EFFECTS ON FUEL CONSUMPTION AND DIESEL ENGINE DEPOSITS FROM NANO-PARTICLE OIL ADDITIVE

INTERIM REPORT
TFLRF No. 409

by
Robert W. Warden
Edwin A. Frame

U.S. Army TARDEC Fuels and Lubricants Research Facility
Southwest Research Institute® (SwRI®)
San Antonio, TX

Allen S. Comfort
U.S. Army RDECOM
Warren, MI

for
U.S. Army TARDEC
Force Projection Technologies
Warren, Michigan

Contract No. W56HZV-09-C-0100 (WD0010)

July 2010

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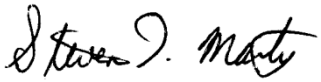

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This project evaluated the effects of a nano-particle additive when blended with MIL-PRF-46167D OEA-30 Arctic Oil as a baseline fluid. Baseline and additized oil were tested for CAT 1K/1N deposits, in-vehicle and dynamometer fuel economy, and lab tests for physical properties and wear metals. Results from the CAT 1K/1N test showed a positive impact on deposits when using the nano-particle additive. Results for both the in-vehicle and dynamometer fuel consumption testing did not indicate that there was a change in fuel consumption either when using the nano-particle additive, or from carry-over effects after changing back to MIL-PRF-46167D oil. High Temperature Benchtop Corrosion Testing produced results showing an increase in wear metal concentration, and copper corrosion appearance when utilizing the nano-particle additive.

15. SUBJECT TERMS

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EXECUTIVE SUMMARY

This project evaluated the effects of a nano-particle additive when blended with MIL-PRF-46167D OEA-30 Arctic Oil as a baseline fluid. Baseline and additized oil were tested for CAT 1K/1N deposits, in-vehicle and dynamometer fuel economy, and lab tests for physical and chemical properties. Analysis of the results from the CAT 1K/1N test indicated a positive impact on deposits when using the nano-particle additive. Both in-vehicle and dynamometer fuel consumption testing did not indicate that there was a change in fuel consumption either when using the nano-particle additive, or from carry-over effects after changing back to the MIL-PRF-46167D oil. High Temperature Benchtop Corrosion Testing produced results showing an increase in wear metal concentration and copper corrosion appearance when utilizing the nano-particle additive. Seal compatibility testing showed that the nano-particle additive did not impact whether the baseline oil passed or failed the MIL-PRF-46167D specified limits.

FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period of December 2009 through July 2010 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank-Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Allen Comfort served as the TARDEC contracting officer's technical representative.

The authors would like to acknowledge the contribution of the TFLRF technical support staff along with the administrative and report-processing support provided by Dianna Barrera. Additionally, the Engine and Emission Research, Petroleum Products Research, and Engine Lubricants Research Departments were very supportive and instrumental in the completion of this project.

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ACRONYMS AND ABBREVIATIONS

%	Percent
˚C	Degrees centigrade
˚F	Degrees Fahrenheit
ASTM	American Society for Testing and Materials
bhp	break horse power
CAT	Caterpillar
COV	Coefficient of Variance
CRC	Coordinating Research Council
cSt	Centistokes
FE	Fuel Economy
FED-STD	Federal Standard
FTP	Federal Test Procedure
GEP	General Engine Products
HTBCT	High Temperature Benchtop Corrosion Test
HwFET	Highway Fuel Economy Test
IF	Inorganic Fullerene
JP-8	A kerosene based jet fuel
lbs	Pounds
LO	Lubricating Oil
mL	milliliter
mph	Miles Per Hour
OEA	Oil Engine Arctic
ppm	parts per million
SAE	Society of Automotive Engineers
SwRI	Southwest Research Institute
TARDEC	Tank Automotive Research, Development and Engineering Center
TFLRF	TARDEC Fuels and Lubricants Research Facility
TM	Technical Manual
TX	Texas
WKD/WDN	Weighted Demerits K/N
Δ	Delta, change

1.0 BACKGROUND AND OBJECTIVE

The U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) performed selected tests to evaluate the use of a commercially available nano-particle additive in engine crankcase lubricants at the request of TARDEC. This additive contains inorganic fullerene-like (IF) nano-particles of WS_2 which were claimed to increase fuel economy and decrease wear in engine components. Although the mechanism is not fully understood, nano-particles may create a transfer film under high contact stresses to aid in the reduction of friction and wear. There is also a potential for the use of lower cost nano-particles as a replacement for more costly, traditional additives. Oil additive performance and characterization was through a variety of tests including CAT 1K/1N, in-vehicle and dynamometer fuel economy tests, and oil analysis. The tests conducted provide a broad picture of performance change compared to the baseline lubricant. While an increase in fuel economy would be desirable, if it comes at the expense of a substantial increase in wear and corrosion it may not be a worthwhile exchange.

2.0 APPROACH

Two drums of qualified MIL-PRF-46167D OEA-30 engine oil were acquired for the purpose of testing. One drum was identified as the baseline oil while the other was treated with the supplied nano-particle additive at an 11:1 ratio by volume. It was determined that this quantity of oil would be sufficient for the entirety of the project, reducing the potential for inconsistencies resulting from separately blended batches of oil. The bulk oil was stored and drawn from as needed for testing. In each aspect of this project, both oils were tested to isolate the effects of the nano-particle additive.

3.0 OIL CHARACTERIZATION AND ANALYSIS

3.1 Physical Properties

Oil characterization was performed through a series of oil analysis tests. Test methods and results are shown in Table 1. It should be noted that due to the extremely viscous nature and dark

color of the nano-additive, no value was obtained for the -48˚C Kinematic Viscosity test of this oil.

Table 1: Physical Property Test Results

Test Procedure	ASTM/FED-STD	MIL-PRF 46167D OEA-30	MIL-PRF 46167D OEA-30 w/ Nano-Additive
Kinematic Viscosity @ 100˚C, cSt	D445	11.06	11.64
Kinematic Viscosity @ 40˚C, cSt	D445	58.58	62.32
Kinematic Viscosity @ -40˚C, cSt	D445	10021.68	17636.74
Kinematic Viscosity @ -48˚C, cSt	D445	52326.13	N/A
Pour Point, ˚C	D97	-60	-60
Stable Pour Point, ˚C	FTM203	-44	-44
Flash Point, ˚C	D92	230	218
Evaporative Loss, % Max	D5800	10.8	10.7
Foaming, Sequence I, mL	D892	0	0
Foaming, Sequence II, mL	D892	0	0

The additive caused an increase in kinematic viscosity for the three temperatures, which data is available. The 100˚C results for both oils meet the MIL-PRF-46167D requirement of 9.3 cSt minimum. Both oils also fall under the -40˚C maximum value of 18,000 cSt. The decrease of 12˚C in flash point is an issue. The oil, to meet the requirements specified by MIL-PRF-46167D, should have a minimum flash point value of 220˚C. While the baseline oil passes this criterion, the addition of nano-particles reduces the flash point to 218˚C, outside of the specified limit.

3.2 Elemental Analysis

Elemental analysis information for both oils was acquired though ASTM D4951 and ASTM D5185. Results are shown in Table 2. It should be noted that the decreases in calcium, phosphorus, and zinc with the addition of the nano-particle additive are expected. Due to the high concentration of additive, the baseline oil was diluted enough to reduce the relative concentrations of these elements in the final product. The increase in sulfur is also consistent with the additive concentration, of which sulfur was a major component.

Table 2: Elemental Analysis

Test Procedure	ASTM/FED-STD	MIL-PRF 46167D OEA-30	MIL-PRF 46167D OEA-30 w/ Nano-Additive
Antimony, ppm	D5185	<1	13
Barium, ppm	D5185	<1	<1
Boron, ppm	D4951	5	<1
Calcium, ppm	D4951	3599	3340
Copper, ppm	D4951	<1	<1
Magnesium, ppm	D4951	13	10
Manganese, ppm	D5185	<1	1
Molybdenum, ppm	D4951	<1	<1
Phosphorus, ppm	D4951	1294	1184
Potassium, ppm	D5185	7	8
Silicon, ppm	D4951	6	6
Sulfur, ppm	D4951	4994	7740
Zinc, ppm	D4951	1437	1327

3.3 High Temperature Bench Top Corrosion Test

Full test results for the High Temperature Bench Top Corrosion Test are available in Appendix A. The test, ASTM D6594, uses metal specimens of copper, lead, tin, and phosphor bronze alloy submerged in the candidate oils. The oil, at an elevated temperature of 135˚C, is blown with air for 168 hours. Upon completion of the test, the copper strip and oil are examined to detect corrosion and corrosion products. The copper strips are rated on an ASTM D130 scale for appearance. Results are shown in Table 3 for wear metal changes in the oils over the course of the test, as well as copper D130 ratings. Along with the baseline and additized oil, results for the ASTMTMC SAE 15W-40 reference oil are shown.

Table 3: ASTM D6594 Results

Lubricant	Δ Copper (ppm)	Δ Lead (ppm)	Δ Tin (ppm)	D130 Rating
Reference Oil - TMC Oil No. 44-1	102	43	0	4b
Baseline Oil - MIL-PRF-46167D	8	91	0	1b
Additized Oil - MIL-PRF-46167D w/ Nano Additive	204	588	2	4b

The additized oil had higher wear metal concentrations following the test than either the reference or baseline fluid. According to ASTM D130, a 4b rating indicates corrosion with a graphite or lusterless black appearance, while a 1b rating is slightly tarnished with a dark orange appearance. The baseline fluid exhibited a better copper strip rating as well as lower wear metal gain than the additized fluid, indicating better corrosion performance without the nano-particles.

3.4 Seal Compatibility Tests

Seal Compatibility Tests were conducted in accordance with ASTM D7216 using the materials specified by MIL-PRF-46167D. The test duration was 336 hours. Results for volume and hardness change are shown in Table 4 with MIL-PRF-46167D specified limits.

Table 4: Seal Compatibility Test Results

Material	Property	Max	Min	Baseline Oil	Additized Oil	Significant Change?
Buna N (Nitrile)	Volume Change, %	5	0	0.32	0.18	Yes
	Hardness Change, points	5	-5	4	3	No
Polyacrylate	Volume Change, %	10	0	-0.24	-0.25	No
	Hardness Change, points	5	0	0	1	Yes
Silicone	Volume Change, %	5	0	20.21	19.32	Yes
	Hardness Change, points	0	-10	-16	-16	No
Fluoroelastomer	Volume Change, %	4	0	0.79	0.8	No
	Hardness Change, points	4	-4	2	2	No
Ethyl Acrylic (Vamac)	Volume Change, %	28	12	10.25	10.08	No
	Hardness Change, points	-6	-18	-3	-3	No

In both the Nitrile and Silicone tests, the addition of the nano-particle additive resulted in a statistically significant difference in volume change from the baseline oil. It also resulted in a very small yet significant increase in hardness change for the additized oil. Aside from these three parameters, there was no other apparent effect on any of the five materials tested. It should be noted that while the additized and baseline fluids were similar in most results, a number of parameters fell outside of the MIL-PRF-46167D specified range. Full results for seals testing are located in Appendix B.

4.0 FUEL ECONOMY TESTING

4.1 FTP-75 and HwFET In-Vehicle Testing

A combined FTP-75 and HwFET driving cycle was used to determine in-vehicle effects on fuel economy and emissions. The FTP-75 is a 31 minute, 11-mile, stop-and-go cycle with a maximum speed of 57 mph and an average speed of 21.6 mph. The HwFET is a 10-mile, 765 second cycle with a maximum speed of 60 mph and an average speed of 48 mph. Additional driving cycle information is located in Appendix C. A diesel powered 2003 Dodge Ram 3500, as shown in Figure 1 was used as the test vehicle on a 48-inch single-roll chassis dynamometer. Fuel economy (FE) was calculated based upon a carbon balance method, and confirmed via a volumetric check. Composite fuel economy was calculated based upon the equation below.

Equation 1: In-Vehicle Fuel Economy Weighting

$$Composite\ FE = \frac{1}{\frac{0.55}{FE_{FTP-75}} + \frac{0.45}{FE_{HwFET}}}$$

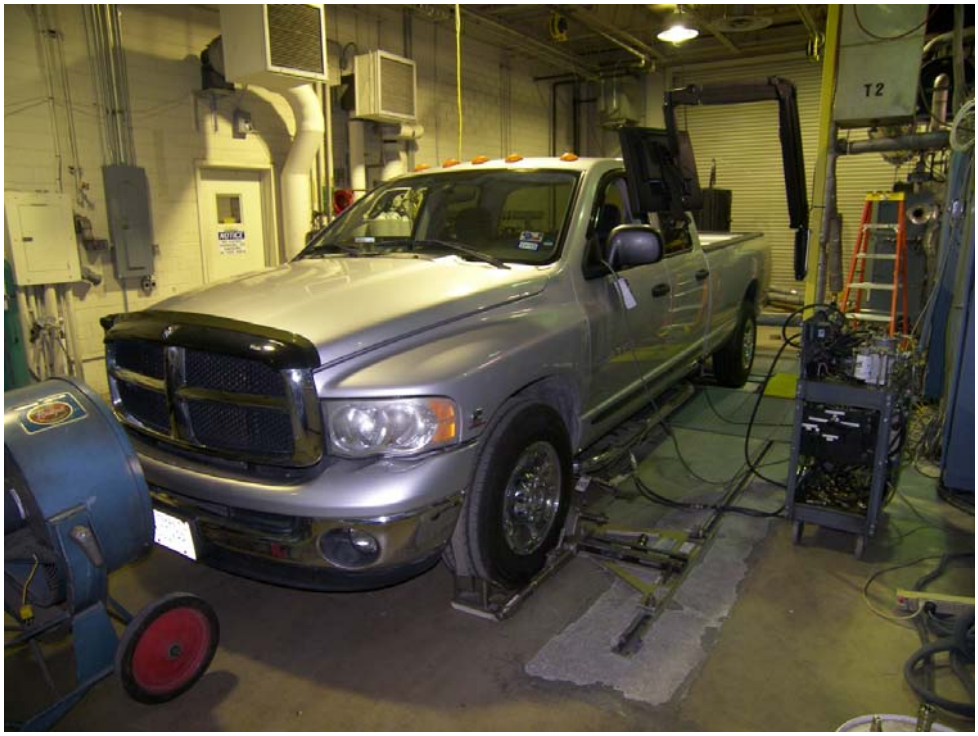


Figure 1: Dodge Ram 3500 for In-Vehicle Testing

The carbon balance composite fuel economy for each test, and the average FE for the baseline and additized oil, are shown in Table 5. Although there is variation from test to test for both oils, the composite fuel economy for the additized oil showed no significant change compared to the baseline test. All data for in-vehicle fuel economy testing, along with emissions measurements from each cycle, is located in Appendix C.

Table 5: FTP-75 and HwFET Results

FTP-75 and HwFET Composite FE		**MPG**
	Run	**FE Cycle**
OEA30 **LO-247669 [Baseline]**	1	18.1500
	2	18.1200
	3	18.4100
	4	18.2900
	5	18.5400
	Average	18.30200
	Standard Deviation	0.17655
	COV	0.96%
OEA 30 with Nano-Particle Additive **LO-248598**	1	18.3000
	2	18.0900
	3	18.2100
	4	18.3600
	5	18.2000
	Average	18.23200
	Standard Deviation	0.10330
	COV	0.57%
	Percent change from OEA30 to Nano	0.38%
	F-Test, two tail	0.324
	Variance: Equal=2, Unequal=3	2
	T-test	4.66E-01
	Statistically significant with 95% CI	NO
	Statistically significant with 99% CI	NO

4.2 Army Lab GEP 6.5T Fuel Consumption Test

The 14-point Army Lab GEP 6.5T Fuel Economy Test developed under Single Common Powertrain Lubricant work was utilized for dynamometer fuel consumption testing of the nano-particle additive. The test consists of 14-points varying in load, speed, and fluid temperatures. Each step is a 10 minute transient followed by a five minute steady state period in which data collection occurs. A summary of the cycle is shown in Table 6.

Table 6: Army Lab GEP 6.5T Fuel Consumption Load Points

Speed (RPM)	Torque (ft-lbs)	Power (hp)	Oil Temperature (F)	Inlet Air Temperature (F)	Fuel Temperature (F)
1100	59.7	12.5	165	75	95
2100	59.7	23.9	180		
1100	99.6	20.9			
1100	179.2	37.5			
1600	99.6	30.3	195		
2100	139.4	55.7			
2600	99.6	49.3	215		
2100	179.2	71.7			
3100	99.6	58.8			
2600	139.4	69.0			
3100	139.4	82.3	245		
2600	179.2	88.7			
2400	302.4	138.2			
2800	250.8	133.7			

The baseline fluid was tested seven times for statistical purposes. The oil was then flushed to the additized oil and seven more tests were run. Following the additized oil testing, baseline oil was refilled in the engine to determine carryover effects. For this oil change, a drain and fill method was used rather than a flush. The second baseline test was also run seven times. Summarized results for all 21 tests are shown in Table 7, with full results available in Appendix D.

Table 7: Fuel Consumption Changes and Carry-Over Effects

Lubricating Oil	Average BSFC	Standard Deviation	Percent Change from Baseline	Statistical Significance
Baseline	0.47656	0.00138	-	-
Additized Oil	0.47648	0.00042	0.02%	No
Baseline 2nd Run	0.47716	0.00324	-0.13%	No

Over the course of testing, it was shown that there was no statistically significant change in fuel consumption due to the nano-particle additive, or carry over effects following its use in the GEP 6.5 liter engine. Significance was evaluated at both 99% and 95% confidence intervals.

In addition to the MIL-PRF-46167D oil, the nano-particle additive was evaluated in the GEP 6.5T Fuel Economy Test using MIL-PRF-2104G SAE 15W-40 as a baseline oil. The oil was additized at the same level as the original baseline and tested in the same engine using a double flush method for oil changes. Viscosity information is shown in Table 8.

Table 8: SAE 15W-40 and Additized Viscosities

Test Procedure	ASTM	MIL-PRF 2104G SAE 15W-40	MIL-PRF 2104G SAE 15W-40 w/ Nano-Additive
Kinematic Viscosity @ 100C	D445	15.41	14.94

While it was thought the lower viscosity would show an improvement in fuel consumption between the two oils, this was not the case. At the 95% confidence interval, the additized SAE 15W-40 oil showed a statistically significant increase in fuel consumption of 0.45%. However, at the 99% confidence interval the change was not statistically significant. Test results are shown in Table 9.

Table 9: SAE 15W-40 Oil Consumption Changes

General Engine Products 6.5 Turbo		BSFC
	Run	FE Cycle
MIL-PRF-2104G SAE 15W-40	1	0.4935
	2	0.4924
	3	0.4920
	4	0.4935
	5	0.4921
	6	0.4915
	Average	0.49250
	Standard Deviation	0.00081
	COV	0.16%
SAE 15W-40 w/ Nano Additive	1	0.4944
	2	0.4935
	3	0.4939
	4	0.4923
	5	0.4942
	6	0.4957
	7	0.4990
	Average	0.49471
	Standard Deviation	0.00216
	COV	0.44%
Percent change from SAE 15W-40 to Nano-Additized		-0.45%
F-Test, two tail		0.048
Variance: Equal=2, Unequal=3		3
T-test		3.71E-02
Statistically significant with 95% CI		YES
Statistically significant with 99% CI		NO

5.0 CATERPILLAR 1K/1N TESTING

The effect of the nano-additive on engine deposits was determined using the CAT 1K/1N test procedure using JP-8 as the test fuel. The use of a fuel other than the official PC-9 fuel made this a non-standard test. Test reports can be found in their entirety in Appendix E. This procedure was conducted in a single cylinder Caterpillar diesel engine with an aluminum piston that is operated at 2100 rpm and 70 bhp for 252 hours. Upon test completion, the engine was

disassembled and the piston was rated for deposits using a standard Coordinating Research Council (CRC) demerit procedure. Piston ring wear and cylinder bore polish were also determined. Results from the CAT 1K/1N tests are shown in Table 10. Results for the Top and Intermediate Groove Fills show a positive impact when using the nano-additive. With a MIL-PRF-46167D limit of 20% for one test Top Groove Fill, the additized oil had a large effect in driving down deposit levels.

Table 10: CAT 1K/1N Test Results

Piston Deposit Rating, Demerits	MIL-PRF 46167D OEA-30	MIL-PRF 46167D OEA-30 w/ Nano-Additive	Δ
WDK/WDN	198.7	159.1	-39.6
Top Groove Fill	18%	7%	-11%
Intermediate Groove Fill	23%	3%	-20%
Top Land Heavy Carbon	1%	1%	0%
Oil Consumption			
Brake Specific Oil Consumption (g/kW-hr)	0.13	0.13	0
End of Test Oil Consumption (g/kW-hr)	0.12	0.1	-0.02

Figure 2: CAT 1K/1N Stand

6.0 SUMMARY AND CONCLUSIONS

Over the course of this project, the data obtained has indicated that there are both beneficial and detrimental aspects to using the selected nano-particle additive. The CAT 1K/1N results for deposits and groove fill indicate oil performance for this particular test superior to the baseline. However, High Temperature Benchtop Corrosion Testing showed the additized oil to have the potential for corrosion problems if utilized in an engine. Seal compatibility produced mixed results, with an increased hardness change for the polyacrylate material, and decreased swelling for Nitrile and Silicone. While these changes were statistically significant, they were not overly meaningful. None of these changes drove results into or out of specification and were small compared to overall values. Fuel consumption testing produced no statistically significant benefit in fuel economy performance between baseline and additized oils, as measured, in both dynamometer and vehicle testing. Additionally, no carry-over effects were noted when returning to the baseline oil. While the deposit benefits are interesting, use of the nano-particle additive did not improve fuel consumption. The lack of improvement in fuel consumption, and flash point being driven out of specification, and significantly increased corrosion, indicate that the nano-additive is not appropriate for use in military vehicles. Additional testing of the nano-particle additive in other applications, such as transmission and axle lubricants, may reveal areas of potential benefits.

7.0 REFERENCES

1. Lubricating Oil, Internal Combustion Engine, Arctic, MIL-PRF-46167D, 2005
2. American Society for Testing and Materials, “Annual Book of A.S.T.M. Standards,” ASTM International, West Conshohocken, PA
3. Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service, MIL-PRF-2104G, 1997

APPENDIX A

Full Test Results For
High Temperature Bench Top Corrosion Test

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Version 20051102

Test Report Cover
Form 1

Conducted for

US ARMY TARDEC

V	V = Valid
	I = Invalid

Test Number			
Bath: 5A	**Bath Run Number:** 178	**Bath Position:** 6	
End-of-Test Date: 20100219		**End-of-Test Time:** 12:56	
Oil Code: MIL-PRF-46167D OEA30			
Formulation/Stand Code:			
Alternate Codes			

In my opinion this test has been conducted in a valid manner in accordance with the Test Method D6594 and the appropriate amendments through the information letter system. The remarks included in this report describe the anomalies associated with test.

Submitted by: **Southwest Research Institute**
Testing Laboratory

Signature

Robert Warden
Typed Name

Engineer
Title

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Summary of Results

Lab: SR	Bath No.: 5A	Bath Run No.: 178	Bath Position: 6
EOT Date: 20100219		EOT Time: 12:56	
Oil Code: MIL-PRF-46167D OEA30		Start Date: 20100212	
Formulation/Stand Code:			
Test Length: 168			

Test Oil Identification	
Reference Oil Test	Non-Reference Oil Test
CMIR Code: 73300	Oil Code: MIL-PRF-46167D OEA30
TMC Oil No.: 44-1	Formulation/Stand Code:
SAE Viscosity: 15W40	SAE Viscosity:
Lab Oil Code: 471163	Lab Oil Code: 471184

Change in Metal Concentration (ppm)							
Metal Type	Number of Runs	Reference Oil Test			Non-Reference Oil Test		
		New Oil Average (ppm)	Used Oil Average (ppm)	Change in Concentration (ppm)	New Oil Average (ppm)	Used Oil Average (ppm)	Change in Concentration (ppm)
Copper	2	<1.0	102.0	102.0	<1.0	8.0	8.0
Lead (Pb)	2	<1.0	43.0	43.0	<1.0	91.0	91.0
Tin (Sn)	2	<1.0	<1.0	0.0	<1.0	<1.0	0.0
Internal	2	50.0	50.0		50.0	50.0	

ASTM D-130 Copper Strip Rating	
Reference Oil Test[A]	Non-Reference Test[A]
4b	1b

Metal Type	Reference Test Specimen		Non-Reference Test Specimen Batch I.D. Number
Copper (Cu)	CC-0742-H3	H	CC-0738-H3
Lead (Pb)	CC-0742-H3		CC-0738-H3
Tin (Sn)	CC-0742-H3		CC-0738-H3
Bronze	CC-0742-H3		CC-0738-H3

[A] *D130 evaluation is not performed. Only D130 rating scale is used.*

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Comments

Lab: SR	**Bath No.:** 5A	**Bath Run No.:** 178	**Bath Position:** 6
EOT Date: 20100219		**EOT Time:** 12:56	
Oil Code: MIL-PRF-46167D OEA30		**Start Date:** 20100212	
Formulation/Stand Code:			

Out-of-Limit Data and Time, Test Modifications and Comments	
Number of Comment Lines	0

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Version 20051102

Test Report Cover
Form 1

Conducted for

US ARMY TARDEC

V	V = Valid
	I = Invalid

Test Number			
Bath: 5A	**Bath Run Number:** 178	**Bath Position:** 5	
End-of-Test Date: 20100219		**End-of-Test Time:** 12:56	
Oil Code: MIL-PRF-46167D 0EA30 w/ Nano Additive			
Formulation/Stand Code:			
Alternate Codes			

In my opinion this test ___has___ been conducted in a valid manner in accordance with the Test Method D6594 and the appropriate amendments through the information letter system. The remarks included in this report describe the anomalies associated with test.

Submitted by: **Southwest Research Institute**
Testing Laboratory

Signature

Robert Warden
Typed Name

Engineer
Title

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Summary of Results

Lab: SR	Bath No.: 5A	Bath Run No.: 178	Bath Position: 5
EOT Date: 20100219		EOT Time: 12:56	
Oil Code: MIL-PRF-46167D 0EA30 w/ Nano Additive		Start Date: 20100212	
Formulation/Stand Code:			
Test Length: 168			

Test Oil Identification	
Reference Oil Test	Non-Reference Oil Test
CMIR Code: 73300	Oil Code: MIL-PRF-46167D 0EA30 w/ Nano Additive
TMC Oil No.: 44-1	Formulation/Stand Code:
SAE Viscosity: 15W40	SAE Viscosity:
Lab Oil Code: 471163	Lab Oil Code: 471183

Change in Metal Concentration (ppm)							
Metal Type	Number of Runs	Reference Oil Test			Non-Reference Oil Test		
		New Oil Average (ppm)	Used Oil Average (ppm)	Change in Concentration (ppm)	New Oil Average (ppm)	Used Oil Average (ppm)	Change in Concentration (ppm)
Copper	2	<1.0	102.0	102.0	<1.0	204.0	204.0
Lead (Pb)	2	<1.0	43.0	43.0	<1.0	588.0	588.0
Tin (Sn)	2	<1.0	<1.0	0.0	<1.0	2.0	2.0
Internal	2	50.0	50.0		50.0	50.0	

ASTM D-130 Copper Strip Rating	
Reference Oil Test[A]	Non-Reference Test[A]
4b	4b

Metal Type	Reference Test Specimen		Non-Reference Test Specimen Batch I.D. Number
Copper (Cu)	CC-0742-H3	H	CC-0737-H3
Lead (Pb)	CC-0742-H3		CC-0737-H3
Tin (Sn)	CC-0742-H3		CC-0737-H3
Bronze	CC-0742-H3		CC-0737-H3

[A] *D130 evaluation is not performed. Only D130 rating scale is used.*

D6594 Evaluation of the Corrosiveness of Diesel Engine Oil at 135°C

Comments

Lab: SR	**Bath No.:** 5A	**Bath Run No.:** 178	**Bath Position:** 5
EOT Date: 20100219		**EOT Time:** 12:56	
Oil Code: MIL-PRF-46167D 0EA30 w/ Nano Additive		**Start Date:** 20100212	
Formulation/Stand Code:			

Out-of-Limit Data and Time, Test Modifications and Comments	
Number of Comment Lines	0

APPENDIX B
Full Test Results for Seal Compatibility Testing

D 7216 -- Engine Oil Elastomer Compatibility
Validity Declaration

Version: 20060725

Conducted for: US ARMY TARDEC

V	V = Valid
	I = Invalid

Elastomer Type	Bath Number	Elastomer Batch	Oil Code	CMIR	SOT Date	SOT Time	EOT Date	EOT Time
Nitrile	15	NBRBC-1	MIL-PRF-46167D OEA30 w/ Nano Additive	73335	20100331	11:20	20100414	11:20
Polyacrylate	6	ACMBC-1		73336	20100401	11:20	20100415	11:20
Fluoroelastomer	32	FKMBC-1		73337	20100402	11:20	20100416	11:20
Silicon	7	VMQBC-1		73338	20100406	11:18	20100420	11:18
Vamac	31	MACBC-4		73352	20100607	8:39	20100621	8:39

Alternate Codes:			

In my opinion this test has been conducted in accordance with Test Method D7216 and the appropriate amendments through the information letter system. The remarks on Form 7 describe any anomolies associated with this test.

Submitted By: Southwest Research Institute (R)

Test Laboratory

Rebecca D Grinfield

Signature

Rebecca D. Grinfield

Test Laboratory

Senior Research Scientist

Title

D 7216 - Engine Oil Elastomer Compatibility
Form 2 - Candidate Data

Sample Code: MIL-PRF-46167D OEA30 w/ Nano Additive	Lab: SR	EOT Date: 20100621
		Test Length: 336

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -3%	5.62	to	-3.62	2.07	0.18
Nitrile		Hardness	+7 pts to -5 pts	8	to	-6	2	3
Batch:	CMIR:	Tensile Strength	+10% to -TMC1006	17.3	to	-41.5	-30.9	-2.8
NBRBC-1	73335	Elongation	+10% to -TMC1006	15.7	to	-58.8	-50.7	-30.4

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -3%	5.62	to	-3.62	1.98	-0.25
Polyacrylate		Hardness	+8 pts to -5 pts	9	to	-6	-3	1
Batch:	CMIR:	Tensile Strength	+18% to -15%	26.2	to	-23.2	-2.3	2.3
ACMBC-1	73336	Elongation	+10% to -35%	19.1	to	-44.1	-3.6	-5.2

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -2%	5.13	to	-2.13	0.37	0.80
Fluoroelastomer		Hardness	+7 pts to -5 pts	8	to	-6	7	2
Batch:	CMIR:	Tensile Strength	+10% to -TMC 1006	13.9	to	-77.4	-71.3	-53.1
FKMBC-1	73337	Elongation	+10% to -TMC 1006	16.3	to	-69.9	-58.2	-44.3

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+TMC 1006 to -3%	24.35	to	-4.50	22.00	19.32
Silicone		Hardness	+5 pts to -TMC 1006	6	to	-21	-18	-16
Batch:	CMIR:	Tensile Strength	+10% to -45%	15.7	to	-50.7	-20.2	-9.8
VMQBC-1	73338	Elongation	+20% to -30%	28.1	to	-38.1	-28.6	-10.2

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	Report	23.08	to	-4.67	20.46	10.08
Vamac		Hardness	Report	6	to	-11	-10	-3
Batch:	CMIR:	Tensile Strength	Report	17.1	to	-18.1	-7.7	-7.1
MACBC-4	73352	Elongation	Report	19.0	to	-33.2	-19.9	-30.5

D 7216 - Engine Oil Elastomer Compatibility
Form 3 - Results Summary - Non-Reference Oil

Sample Code: MIL-PRF-46167D OEA30 w/ Nano Additive Lab: SR
Lab Oil Code: 472685

Elastomer Type: Nitrile Elastomer Batch Code: NBRBC-1
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100331 EOT Date: 20100414 Bath Number: 15

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
100	336	0.16	2	3.3	-27.0
		0.15	3	-4.2	-32.0
		0.25	3	-4.9	-29.8
		0.22	4	-11.1	-34.3
		0.13	4	2.5	-30.4
		0.19	4	-2.6	-28.8
Average		0.18	3	-2.8	-30.4
Standard Deviation		0.05	0.82	5.30	2.54

Elastomer Type: Poly Acrylate Elastomer Batch Code: ACMBC-1
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100401 EOT Date: 20100415 Bath Number: 6

150	336	-0.15	1	-1.8	1.7
		-0.29	0	1.4	-16.8
		-0.23	1	2.7	-5.3
		-0.30	1	7.5	-4.1
		-0.30	1	8.6	0.3
		-0.24	0	-4.7	-7.2
Average		-0.25	1	2.3	-5.2
Standard Deviation		0.06	0.52	5.17	6.60

Elastomer Type: Fluoroelastomer Elastomer Batch Code: FKMBC-1
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100402 EOT Date: 20100416 Bath Number: 32

150	336	0.80	1	-55.6	-49.8
		0.84	2	-52.9	-40.9
		0.81	2	-51.5	-37.2
		0.73	1	-49.9	-52.3
		0.73	2	-56.4	-51.5
		0.86	2	-52.2	-34.1
Average		0.80	2	-53.1	-44.3
Standard Deviation		0.05	0.52	2.48	7.90

Elastomer Type: Silicon Elastomer Batch Code: VMQBC-1
SOT Time: 11:18 EOT Time: 11:18
SOT Date: 20100406 EOT Date: 20100420 Bath Number: 7

150	336	19.32	-17	-9.9	-4.6
		19.61	-17	-10.7	-11.7
		19.53	-17	-10.3	-11.9
		19.19	-16	-9.0	-6.9
		19.05	-16	-8.8	-5.6
		19.23	-16	-10.4	-20.2
Average		19.32	-16	-9.8	-10.2
Standard Deviation		0.21	0.55	0.78	5.81

D 7216 - Engine Oil Elastomer Compatibility
Form 4 - Results Summary - Non-Reference Oil - Vamac

Sample Code: MIL-PRF-46167D OEA30 w/ Nano Additive Lab: SR
Lab Oil Code: 472685

Elastomer Type: Vamac Elastomer Batch Code: MACBC-4
SOT Time: 8:39 EOT Time: 8:39
SOT Date: 20100607 EOT Date: 20100621 Bath Number: 31

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
150	336	10.11	-2	-9.4	-35.6
		10.26	-3	-6.4	-26.3
		10.41	-3	-10.0	-28.3
		9.73	-4	-6.4	-24.6
		9.99	-4	-7.2	-33.1
		9.97	-3	-3.3	-35.0
Average		10.08	-3	-7.1	-30.5
Standard Deviation		0.24	0.75	2.41	4.70

D 7216 - Engine Oil Elastomer Compatibility
Form 5 - Results Summary - Reference Oil

Lab Oil Code:	472685	Lab:	SR

CMIR: 73335 TMC Industry Oil Code:
Elastomer Type: Nitrile Elastomer Batch Code: NBRBC-9
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100331 EOT Date: 20100414 Bath Number: 15

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
100	336	2.15	2	-31.0	-51.7
		2.13	3	-31.0	-46.7
		2.10	2	-32.3	-54.7
		2.06	3	-27.9	-52.7
		1.92	3	-33.9	-47.6
		2.05	2	-29.3	-50.8
Average		2.07	2	-30.9	-50.7
Standard Deviation		0.08	0.55	2.12	3.05

CMIR: 73336 TMC Industry Oil Code:
Elastomer Type: Polyacrylate Elastomer Batch Code: ACMBC-9
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100401 EOT Date: 20100415 Bath Number: 6

150	336	2.02	-2	-0.9	-1.0
		1.96	-3	-7.6	-17.4
		1.91	-3	0.8	-10.8
		2.01	-3	4.2	-6.2
		1.98	-3	-3.2	-3.1
		1.99	-2	-6.9	16.8
Average		1.98	-3	-2.3	-3.6
Standard Deviation		0.04	0.52	4.56	11.59

CMIR: 73337 TMC Industry Oil Code:
Elastomer Type: 3-PC9 (FKM) Elastomer Batch Code: FKMBC-1
SOT Time: 11:20 EOT Time: 11:20
SOT Date: 20100402 EOT Date: 20100416 Bath Number: 32

150	336	0.29	7	-71.2	-52.6
		0.17	8	-71.7	-52.7
		0.45	7	-71.4	-52.2
		0.44	7	-71.2	-63.8
		0.43	7	-71.2	-72.6
		0.46	8	-71.1	-55.0
Average		0.37	7	-71.3	-58.2
Standard Deviation		0.12	0.52	0.22	8.33

CMIR: 73338 TMC Industry Oil Code:
Elastomer Type: Silicone Elastomer Batch Code: VMQBC-1
SOT Time: 11:18 EOT Time: 11:18
SOT Date: 20100406 EOT Date: 20100420 Bath Number: 7

150	336	21.81	-19	-17.2	-24.8
		22.10	-19	-34.4	-48.0
		22.02	-18	-15.8	-26.7
		22.07	-18	-21.6	-31.5
		21.89	-17	-15.7	-27.6
		22.12	-18	-16.2	-13.3
Average		22.00	-18	-20.2	-28.6
Standard Deviation		0.12	0.75	7.32	11.30

D 7216 - Engine Oil Elastomer Compatibility
Form 6 - Results Summary - Reference Oil - Vamac

Lab Oil Code:	472685	Lab:	SR

CMIR: 73352
TMC Industry Oil Code:
Elastomer Type: Vamac
Elastomer Batch Code: MACBC-4
SOT Time: 8:39 EOT Time: 8:39
SOT Date: 20100607 EOT Date: 20100621 Bath Number: 31

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
150	336	20.45	-10	-10.8	-19.4
		20.66	-10	-10.0	-28.2
		20.61	-10	-14.0	-30.9
		20.24	-10	-2.4	-10.8
		20.50	-10	-6.6	-16.0
		20.28	-11	-2.5	-13.9
Average		20.46	-10	-7.7	-19.9
Standard Deviation		0.17	0.41	4.71	8.05

D 7216 - Engine Oil Elastomer Compatibility
Form 7 - Comments

Sample Code: MIL-PRF-46167D OEA30 w/ Nano Additive	Lab: SR	EOT Date: 20100621

Number of Comment Lines: 0

D 7216 -- Engine Oil Elastomer Compatibility
Validity Declaration

Version: 20060725

Conducted for: US ARMY TARDEC

V	V = Valid
	I = Invalid

Elastomer Type	Bath Number	Elastomer Batch	Oil Code	CMIR	SOT Date	SOT Time	EOT Date	EOT Time
Nitrile	15	NBRBC-1	MIL-PRF-46167D OEA30	73335	20100331	11:20	20100414	11:20
Polyacrylate	6	ACMBC-1		73336	20100401	11:20	20100415	11:20
Fluoroelastomer	32	FKMBC-1		73337	20100402	11:20	20100416	11:20
Silicon	7	VMQBC-1		73338	20100406	11:18	20100420	11:18
Vamac	31	MACBC-4		73352	20100607	8:39	20100621	8:39

Alternate Codes:			

In my opinion this testhas been conducted in accordance with Test Method D7216 and the appropriate amendments through the information letter system. The remarks on Form 7 describe any anomolies associated with this test.

Submitted By: Southwest Research Institute (R)

Test Laboratory

Signature

Rebecca D. Grinfield

Test Laboratory

Senior Research Scientist

Title

D 7216 - Engine Oil Elastomer Compatibility
Form 2 - Candidate Data

Sample Code: MIL-PRF-46167D OEA30	Lab: SR	EOT Date: 20100621 Test Length: 336

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -3%	5.62	to	-3.62	2.07	0.32
Nitrile		Hardness	+7 pts to -5 pts	8	to	-6	2	4
Batch:	CMIR:	Tensile Strength	+10% to -TMC1006	17.3	to	-41.5	-30.9	-3.9
NBRBC-1	73335	Elongation	+10% to -TMC1006	15.7	to	-58.8	-50.7	-35.5

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -3%	5.62	to	-3.62	1.98	-0.24
Polyacrylate		Hardness	+8 pts to -5 pts	9	to	-6	-3	0
Batch:	CMIR:	Tensile Strength	+18% to -15%	26.2	to	-23.2	-2.3	-5.2
ACMBC-1	73336	Elongation	+10% to -35%	19.1	to	-44.1	-3.6	0.9

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+5% to -2%	5.13	to	-2.13	0.37	0.79
Fluoroelastomer		Hardness	+7 pts to -5 pts	8	to	-6	7	2
Batch:	CMIR:	Tensile Strength	+10% to -TMC 1006	13.9	to	-77.4	-71.3	-47.1
FKMBC-1	73337	Elongation	+10% to -TMC 1006	16.3	to	-69.9	-58.2	-38.8

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	+TMC 1006 to -3%	24.35	to	-4.50	22.00	20.21
Silicone		Hardness	+5 pts to -TMC 1006	6	to	-21	-18	-16
Batch:	CMIR:	Tensile Strength	+10% to -45%	15.7	to	-50.7	-20.2	-11.5
VMQBC-1	73338	Elongation	+20% to -30%	28.1	to	-38.1	-28.6	-9.2

Elastomer Identification	TMC Identification	Parameter	Specification Limit	Acceptance Limits Updated on:			Reference Result	Candidate Result
Type:	Industry Oil:	Volume Change	Report	23.08	to	-4.67	20.46	10.25
Vamac		Hardness	Report	6	to	-11	-10	-3
Batch:	CMIR:	Tensile Strength	Report	17.1	to	-18.1	-7.7	-0.7
MACBC-4	73352	Elongation	Report	19.0	to	-33.2	-19.9	-32.8

D 7216 - Engine Oil Elastomer Compatibility
Form 3 - Results Summary - Non-Reference Oil

Sample Code: MIL-PRF-46167D OEA30 Lab: SR
Lab Oil Code: 472686

Elastomer Type: Nitrile — Elastomer Batch Code: NBRBC-1
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100331 — EOT Date: 20100414 — Bath Number: 15

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
100	336	0.36	5	0.4	-32.2
		0.27	5	-4.1	-32.1
		0.29	5	-10.1	-38.3
		0.33	4	-3.7	-37.9
		0.32	4	-1.4	-37.4
		0.34	3	-4.4	-35.2
Average		0.32	4	-3.9	-35.5
Standard Deviation		0.03	0.82	3.56	2.82

Elastomer Type: Polyacrylate — Elastomer Batch Code: ACMBC-1
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100401 — EOT Date: 20100415 — Bath Number: 6

150	336	-0.26	0	4.5	7.0
		-0.31	-1	-11.1	3.5
		-0.23	-1	-11.7	3.8
		-0.20	0	-2.9	-2.9
		-0.15	-1	-8.4	2.9
		-0.28	0	-1.9	-8.7
Average		-0.24	0	-5.2	0.9
Standard Deviation		0.06	0.55	6.29	5.71

Elastomer Type: Fluoroelastomer — Elastomer Batch Code: FKMBC-1
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100402 — EOT Date: 20100416 — Bath Number: 32

150	336	0.85	3	-47.6	-42.7
		0.75	2	-50.3	-42.0
		0.78	2	-47.5	-39.1
		0.85	2	-46.0	-37.1
		0.79	2	-48.2	-39.5
		0.72	2	-42.9	-32.5
Average		0.79	2	-47.1	-38.8
Standard Deviation		0.05	0.41	2.48	3.70

Elastomer Type: Silicon — Elastomer Batch Code: VMQBC-1
SOT Time: 11:18 — EOT Time: 11:18
SOT Date: 20100406 — EOT Date: 20100420 — Bath Number: 7

150	336	19.71	-17	-9.8	-7.6
		20.31	-16	-10.9	-13.4
		19.83	-17	-20.4	-22.9
		20.45	-17	-12.1	0.4
		20.55	-16	-8.0	3.4
		20.40	-16	-8.0	-14.8
Average		20.21	-16	-11.5	-9.2
Standard Deviation		0.35	0.55	4.63	9.90

D 7216 - Engine Oil Elastomer Compatibility
Form 4 - Results Summary - Non-Reference Oil - Vamac

Sample Code: MIL-PRF-46167D OEA30 Lab: SR
Lab Oil Code: 472686

Elastomer Type: Vamac Elastomer Batch Code: MACBC-4
SOT Time: 8:39 EOT Time: 8:39
SOT Date: 20100607 EOT Date: 20100621 Bath Number: 31

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
150	336	10.11	-3	1.6	-31.7
		10.48	-2	3.0	-34.6
		10.16	-3	-1.6	-31.9
		10.44	-3	-5.0	-31.6
		10.27	-2	-2.0	-32.7
		10.05	-3	-0.2	-34.4
Average		10.25	-3	-0.7	-32.8
Standard Deviation		0.18	0.52	2.84	1.36

D 7216 - Engine Oil Elastomer Compatibility
Form 5 - Results Summary - Reference Oil

Lab Oil Code:	472686	Lab:	SR

CMIR: 73335 — TMC Industry Oil Code:
Elastomer Type: Nitrile — Elastomer Batch Code: NBRBC-9
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100331 — EOT Date: 20100414 — Bath Number: 15

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
100	336	2.15	2	-31.0	-51.7
		2.13	3	-31.0	-46.7
		2.10	2	-32.3	-54.7
		2.06	3	-27.9	-52.7
		1.92	3	-33.9	-47.6
		2.05	2	-29.3	-50.8
Average		2.07	2	-30.9	-50.7
Standard Deviation		0.08	0.55	2.12	3.05

CMIR: 73336 — TMC Industry Oil Code:
Elastomer Type: Polyacrylate — Elastomer Batch Code: ACMBC-9
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100401 — EOT Date: 20100415 — Bath Number: 6

150	336	2.02	-2	-0.9	-1.0
		1.96	-3	-7.6	-17.4
		1.91	-3	0.8	-10.8
		2.01	-3	4.2	-6.2
		1.98	-3	-3.2	-3.1
		1.99	-2	-6.9	16.8
Average		1.98	-3	-2.3	-3.6
Standard Deviation		0.04	0.52	4.56	11.59

CMIR: 73337 — TMC Industry Oil Code:
Elastomer Type: 3-PC9 (FKM) — Elastomer Batch Code: FKMBC-1
SOT Time: 11:20 — EOT Time: 11:20
SOT Date: 20100402 — EOT Date: 20100416 — Bath Number: 32

150	336	0.29	7	-71.2	-52.6
		0.17	8	-71.7	-52.7
		0.45	7	-71.4	-52.2
		0.44	7	-71.2	-63.8
		0.43	7	-71.2	-72.6
		0.46	8	-71.1	-55.0
Average		0.37	7	-71.3	-58.2
Standard Deviation		0.12	0.52	0.22	8.33

CMIR: 73338 — TMC Industry Oil Code:
Elastomer Type: Silicone — Elastomer Batch Code: VMQBC-1
SOT Time: 11:18 — EOT Time: 11:18
SOT Date: 20100406 — EOT Date: 20100420 — Bath Number: 7

150	336	21.81	-19	-17.2	-24.8
		22.10	-19	-34.4	-48.0
		22.02	-18	-15.8	-26.7
		22.07	-18	-21.6	-31.5
		21.89	-17	-15.7	-27.6
		22.12	-18	-16.2	-13.3
Average		22.00	-18	-20.2	-28.6
Standard Deviation		0.12	0.75	7.32	11.30

D 7216 - Engine Oil Elastomer Compatibility
Form 6 - Results Summary - Reference Oil - Vamac

Lab Oil Code:	472686	Lab:	SR

CMIR:	73352			TMC Industry Oil Code:	
Elastomer Type:	Vamac			Elastomer Batch Code:	MACBC-4
SOT Time:	8:39	EOT Time:	8:39		
SOT Date:	20100607	EOT Date:	20100621	Bath Number:	31

Test Temperature, °C	Test Duration, Hours	Volume Change, %	Hardness Change, Points	Tensile Strength Change, %	Elongation Change, %
150	336	20.45	-10	-10.8	-19.4
		20.66	-10	-10.0	-28.2
		20.61	-10	-14.0	-30.9
		20.24	-10	-2.4	-10.8
		20.50	-10	-6.6	-16.0
		20.28	-11	-2.5	-13.9
Average		20.46	-10	-7.7	-19.9
Standard Deviation		0.17	0.41	4.71	8.05

D 7216 - Engine Oil Elastomer Compatibility
Form 7 - Comments

Sample Code: MIL-PRF-46167D OEA30	Lab: SR	EOT Date: 20100621

Number of Comment Lines: 0

APPENDIX C
In-Vehicle Fuel Economy Test Results

SOUTHWEST RESEARCH INSTITUTE®

6220 CULEBRA RD. 78238-5166 • P.O. DRAWER 28510 78228-0510 • SAN ANTONIO, TEXAS, USA • (210) 684-5111 • WWW.SWRI.ORG

ENGINE, EMISSIONS AND VEHICLE RESEARCH DIVISION

June 15, 2010

Mr. Edwin Frame
Southwest Research Institute
6220 Culebra Road
San Antonio, TX 78238

Email: edwin.fram e@swri.org

Subject: Southwest Research Institute® Project 03.14734.10.200 Final Letter Report, "FTP/Fuel Economy and Emissions Testing"

Dear Mr. Frame:

This report contains an evaluation of the fuel economy for one candidate and one baseline crankcase engine oil on a 2003 Dodge Ra m 3500. This project was pe rformed for Southwest Research Institute's (SwRI®) Mr. Robert Warden of the Fuels, Lubricants, and Fluids Application Section, Fuels and Lubricants Technology Divi sion, by the Light-Duty Vehicle Em issions (LDVE) Section, Engine, Em issions and Research Division, SwRI. Testing was carried out from February to April 2010. The LDVE project leader was Ms. Suzanne Timmons.

1.0 TECHNICAL APPROACH

The objective of this program was to c onduct fuel economy and e missions testing on a diesel-fueled medium-duty truck to determ ine the effects on a single can didate crankcase engine oil in com parison to a baseline oil. Evalua tions were conducted for both the baseline and candidate oils by operating the test vehicle on 48-inch cha ssis dynamom eter over replicate Federal Test Procedure (FTP-75) and Highway Fuel Econom y Test (HW FET) driving cycles. Details of the test program are given as follows.

2.0 TEST VEHICLE

The test vehicle was obtained through a vehi cle solic itation at SwRI. The results of the solicitation yielded six possible can didate vehicles. Each vehicle was inspected for transm ission and oil leaks and verified to be in stock cond ition. The project m anager, Mr. Robert W arden, chose a 2003 Dodge Ram 3500 truck with approximately 93,000 miles on the odometer.

3.0 CHASSIS DYNAMOMETER SETUP

The Dodge Ra m was te sted on a Horiba 48-in ch single-roll chassis dynam ometer. This dynamometer electrically simulates inertia weights up to 15,000 lb over the FTP-75 and HW FET, and provides programmable road load simulation of up to 200 hp continuous at 65 mph. Chassis dynamometer coefficients were obtained by dynamometer road-load de rivation. The target coefficients were obtained fr om The Chrysler Group LLC. Th e dynamom eter settings for the Dodge Ram are given in Table 1.

TABLE 1. DYNAMOMETER LOAD SETTINGS

a set coefficient	66.15 lbs
b set coefficient	0.1974 lbs/mph
c set coefficient	0.04055 lbs/mph^2
Equivalent Test Weight	8,500 lbs

4.0 TEST FLUIDS

The fuel used for testing was a single batch of Halterm ann No. 2 certification diesel, Batch No. HF0582, SwRI Fuel Code EM-6917- F. A certificate of analysis for this fuel is provided i n Appendix A. Prior to the initiation of test ing, a one-tim e double flush of the fuel tank was performed as shown in Table 2.

TABLE 2. FUEL CHANGE PROCEDURE

STEP	DESCRIPTION
1.	Drain existing fuel
2.	Add two gallons of test fuel
3.	Idle vehicle for 5 minutes
4.	Drain remaining fuel
5.	Add two gallons of test fuel
6.	Idle vehicle for 5 minutes
7.	Drain remaining fuel
8.	Fill fuel tank with test fuel

The test o ils (baseline and additized candidate) were supplied by the F uels, Lubricants, and Fluids Application Section (FLFAS). A quadruple flush was perform ed with each engine oil. T he engine oil flush was perfor med using the check lis t sheet shown in Appendix B. The baseline and candidate engine oils are listed in Table 3 below.

TABLE 3. ENGINE OILS

ENGINE OIL	IDENTIFICATION
Baseline LO247	699
Candidate LO248	598

5.0 DRIVING CYCLES

Testing utilized the FTP-75 and HWFET drivin g cycles. Th e FTP-75 simulates an 11-m ile, stop-and-go trip which is intended to be representative of urban dr iving. The trip takes 31 m inutes and has 23 stops. About 18 percent of the time is spent idling, as in waiting at traffic lights or in rush hour traffic. The m aximum speed is 57 m ph, a nd the average speed is 21.6 m ph. The vehicle is initially started after being parked overnight at room temperature (referred to as a cold start).

An FTP-75 consists of a cold-start, 505-second, cold transient phase (Phase 1), followed immediately by an 867-second stabilized phase (Phase 2). Following the stabilized phase, the vehicle is allowed to soak for 10 minutes with the engine turned off before proceeding with a hot-start, 505-second, hot transient phase (Phase 3) to complete the test. A speed versus time illustration of the FTP-75 driving cycle is given in Figure 1.

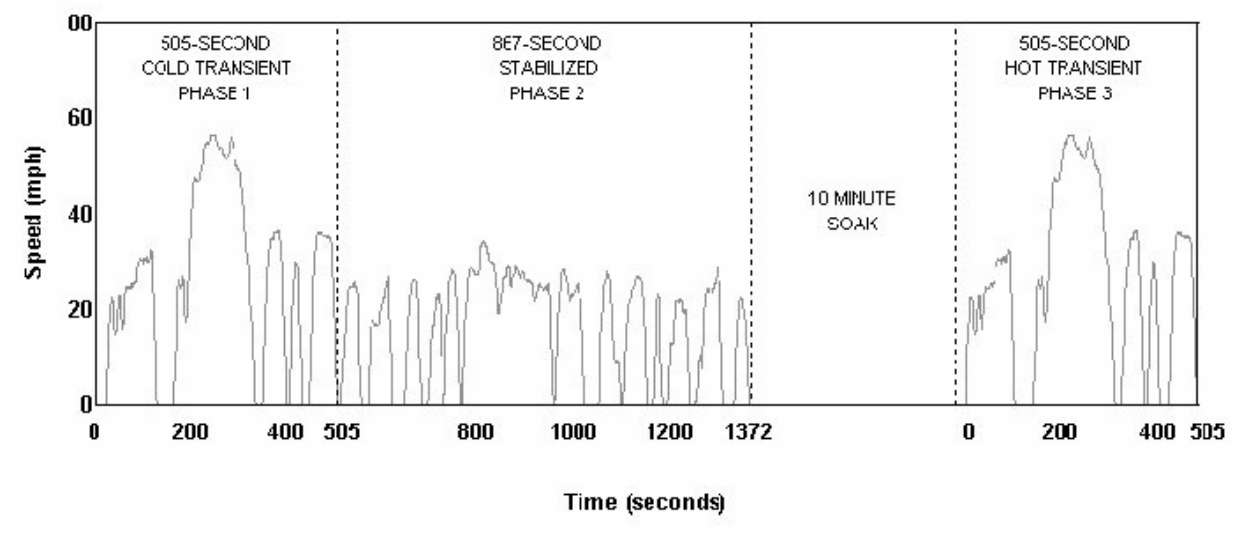


FIGURE 1. FTP-75 DRIVING CYCLE

The emissions from each phase are collected in a separate bag, analyzed and expressed in g/mile. The weighting factors are 0.43 for the cold start, 1.0 for the transient phase and 0.57 for the hot start phase.

The HWFET is a hot running cycle that commences immediately following the end of the FTP-75. The HWFET represents a mixture of "non-city" driving, including segments corresponding to rural roads and interstate highways. The test simulates a 10-mile trip and averages 48 mph. The maximum speed is 60 mph and the test cycle is 765 seconds in duration. The test is run with the engine warmed up and has little idling time and no stops (except at the end of the test). A typical HWFET begins by driving the vehicle over an initial HWFET cycle (warm-up phase) to prepare or condition the vehicle for the actual test. When the warm-up phase is complete, sampling begins immediately with the start of the second cycle (sampling phase). No “soak” is performed between cycles. The HWFET driving cycle is presented in Figure 2.

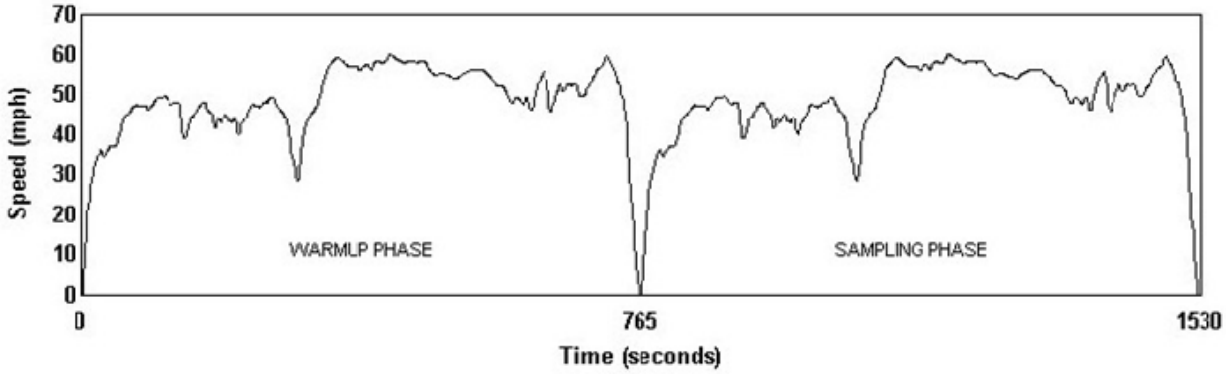


FIGURE 2. HWFET DRIVING SCHEDULE

6.0 EXHAUST EMISSIONS AND FUEL ECONOMY MEASUREMENTS

Gaseous emissions were determined in a manner consistent with EPA protocols for light-duty emission testing as given in the CFR, Title 40, Part 86. A constant volume sampler was used to collect proportional dilute exhaust in Kynar bags for analysis of carbon monoxide (CO), carbon dioxide (CO_2), and methane (CH_4). Total hydrocarbons (THC) and oxides of nitrogen (NO_X) were measured continuously from the dilution tunnel and the results integrated. Concurrently, a proportional sample of dilute exhaust was drawn through Whatman 47 mm PTFE filters for a gravimetric determination of particulate matter mass emissions. Exhaust emissions were analyzed as shown below.

CONSTITUENT	ANALYSIS METHOD
Total Hydrocarbon	Heated Flame Ionization Detector
Methane Gas	Chromatography
Carbon Monoxide	Non-Dispersive Infrared Analysis
Carbon Dioxide	Non-Dispersive Infrared Analysis
Oxides of Nitrogen	Chemiluminescence Analysis
Particulate Matter	Gravimetric Measurement

Fuel economy was calculated for both the FTP-75 and the HWFET cycles, which were used to determine city and highway fuel economy, respectively. A composite fuel economy value was calculated based on the weighted average of the FTP-75 (55%) and HWFET (45%) fuel economy values. The equation is:

$$\text{Composite Fuel Economy} = \frac{1}{\frac{0.55}{FE_{FTP\text{-}75}} + \frac{0.45}{FE_{HWFET}}}$$

7.0 RESULTS

The carbon balance composite fuel economy (FE) for each test, and the average FE for the baseline and candidate oils, are shown in Figure 3. The FE was also measured volumetrically for verification. In Figure 3, the symbols representing the average composite FE at the average vehicle odometer reading for the baseline and candidate oils are shaded, where the individual tests are not. Results are presented on a phase-by-phase basis for both carbon balance and volumetric methods in Appendix C. Although there is variation from test to test for both oils, the FE for the additized candidate oil did not change significantly compared to the baseline.

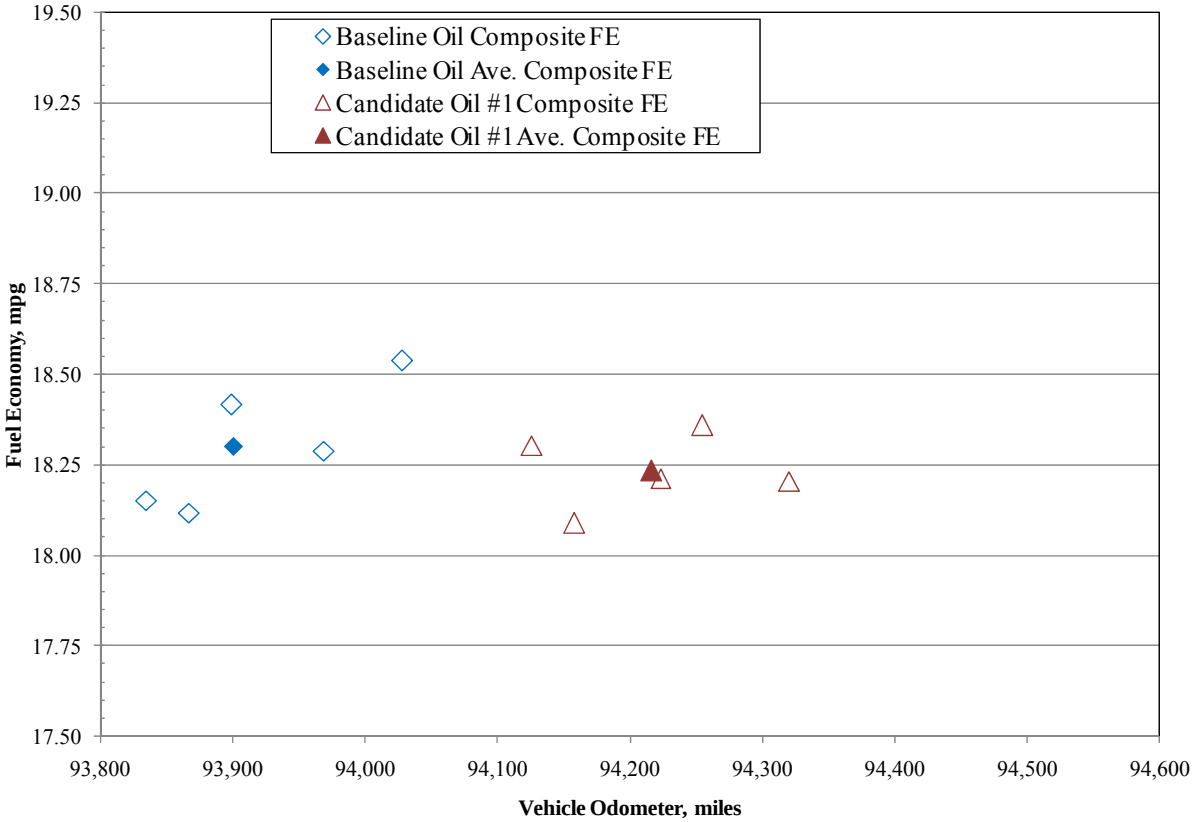


FIGURE 3. BASELINE AND CANDIDATE OIL CARBON BALANCE COMPOSITE FE

The regulated emissions for the baseline and candidate oils are provided in Tables 4 and 5 for each test. The data sheets for each individual test are provided in Appendix D.

TABLE 4. FTP-75, HWFET EMISSIONS SUMMARY: BASELINE OIL

93,609 Miles	FTP Emissions						HFET Emissions					
BL 1	THC g/mi	CO g/mi	NO_X g/mi	CH_4 g/mi	NMHC g/mi	PM mg/mi	THC g/mi	CO g/mi	NO_X g/mi	CH_4 g/mi	NMHC g/mi	PM mg/mi
BOI-DR1-T2R	0.187	2.382	8.998	ND	0.187	81.8	0.123	1.162	6.291	ND	0.123	46.6
BOI-DR1-T3R	0.204	2.714	9.079	ND	0.204	84.6	0.122	1.298	6.373	ND	0.122	43.8
BOI-DR1-T4R	0.222	2.748	9.046	ND	0.222	80.5	0.119	1.268	6.389	ND	0.119	46.9
BOI-DR1-T5R	0.217	2.761	8.872	ND	0.217	83.8	0.123	1.276	6.448	ND	0.123	58.0
DRI-040210-T7R	0.201	2.789	9.448	ND	0.201	86.0	0.125	1.254	6.639	ND	0.125	43.0
DRI-040310-T8R	0.148	2.763	9.376	ND	0.148	82.4	0.126	1.196	6.901	ND	0.126	45.3
AVG	0.185	2.581	9.133	ND	0.185	85.2	0.120	1.217	6.449	ND	0.120	49.1
STD	0.030	0.215	0.199	ND	0.030	8.6	0.006	0.075	0.208	ND	0.006	5.3
COV	16.0%	8.3%	2.2%	ND	16.1%	10.1%	4.6%	6.2%	3.2%	ND	4.6%	10.8%

ND - Not Detected

TABLE 5. FTP-75, HWFET EMISSIONS SUMMARY: CANDIDATE OIL

94,126 Miles	FTP Emissions						HFET Emissions					
Candidate Oil #1	THC g/mi	CO g/mi	NO_X g/mi	CH_4 g/mi	NMHC g/mi	PM mg/mi	THC g/mi	CO g/mi	NO_X g/mi	CH_4 g/mi	NMHC g/mi	PM mg/mi
CO1-DR1-T2	0.235	2.790	9.237	ND	0.235	88.5	0.136	1.308	6.406	ND	0.136	53.9
CO1-DR1-T3	0.221	2.742	9.417	ND	0.221	82.2	0.134	1.226	6.658	ND	0.134	44.9
CO1-DR1-T5	0.216	2.803	9.501	ND	0.216	85.1	0.135	1.319	6.622	ND	0.135	45.9
CO1-DR1-T1R	0.239	2.881	9.063	ND	0.239	85.9	0.134	1.382	6.390	ND	0.134	49.8
CO1-DR1-T7	0.218	2.833	9.340	ND	0.218	86.7	0.127	1.262	6.561	ND	0.127	45.9
AVG	0.226	2.810	9.312	ND	0.226	85.7	0.133	1.299	6.527	ND	0.133	48.1
STD	0.010	0.052	0.170	ND	0.010	2.3	0.004	0.059	0.123	ND	0.004	3.8
COV	4.6%	1.8%	1.8%	ND	4.6%	2.7%	2.7%	4.6%	1.9%	ND	2.7%	7.8%

No T6 test was conducted
ND - Not Detected

APPENDIX D
Army Lab 6.5T Fuel Consumption Tests

ARMY LAB 6.5T FUEL ECONOMY TEST RESULTS

General Engine Products 6.5 Turbo			BSFC
		Run	FE Cycle
OEA 30 **[Baseline]**		1	0.4735
		2	0.4773
		3	0.4774
		4	0.4770
		5	0.4763
		6	0.4772
		7	0.4771
	Average		0.47656
	Standard Deviation		0.00138
	COV		0.29%
OEA 30 with Nano-particle Additive		1	0.4770
		2	0.4764
		3	0.4766
		4	0.4759
		5	0.4767
		6	0.4760
		7	0.4767
	Average		0.47648
	Standard Deviation		0.00042
	COV		0.09%
	Percent change from OEA30 to Nano-particle Additive		0.02%
		F-Test, two tail	0.010
		Variance: Equal=2, Unequal=3	3
		T-test	8.86E-01
	Statistically significant with 95% CI		NO
	Statistically significant with 99% CI		NO

General Engine Products 6.5 Turbo			BSFC
		Run	FE Cycle
OEA 30 **[Baseline]**		1	0.4735
		2	0.4773
		3	0.4774
		4	0.4770
		5	0.4763
		6	0.4772
		7	0.4771
	Average		0.47656
	Standard Deviation		0.00138
	COV		0.29%
OEA 30 **[Re-Baseline]**		1	0.4779
		2	0.4751
		3	0.4742
		4	0.4729
		5	0.4790
		6	0.4789
		7	0.4821
	Average		0.47716
	Standard Deviation		0.00324
	COV		0.68%
	Percent change in carry-over		-0.13%
	F-Test, two tail		0.056
	Variance: Equal=2, Unequal=3		2
	T-test		6.59E-01
	Statistically significant with 95% CI		NO
	Statistically significant with 99% CI		NO

APPENDIX E

Caterpillar 1K/1N Test Reports

1K/1N

Version 20090901

Title / Validity Declaration Page

Method 1N

Conducted for

SOUTHWEST RESEARCH INSTITUTE

N	V = Valid
	I = Invalid
	N = Results cannot be Interpreted as Respresentative of Oil Performance (Non-Reference Oil) and shall not be used for Multiple Test Acceptance Criteria

NR	RO = Reference Oil Test
	NR = All Other Tests

Y	Was This Test Run Under a Valid Calibration? (Y/N)

	Lab is Currently Operating Under an LTMS Precision Alarm *
	Stand is Currently Operating Under an LTMS Precision Alarm *

** Check box only if YES*

Test Number		
Test Stand: 62	**Engine Run No.:** 242	
EOT Time: 04:16	**EOT Date:** 20100221	
Oil Code ** MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900		
Formulation / Stand Code: A		
Alternate Codes: B		

In my opinion this test has not been conducted in a valid manner in accordance with ASTM Test Method D 6750 (1K/1N) and the appropriate amendments through the information letter system. The remarks included in the report describe the anomalies associated with this test.

The results of this report relate only to the items tested.

***CMIR or Non-Reference Oil Code*

A ACC -Registered Tests Only

B When Provided or Required by Client

Submitted by:

Southwest Research Institute (R)
Testing Laboratory

Signature

James F. McCord
Typed Name

Senior Research Engineer
Title

1K/1N
Test Report Summary
Form 1

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242		
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Start Date: 20100210	Total Test Length: 252	TMC Oil Type:
Laboratory Internal Oil Code: LO-247699		
Number of Test Starts Since Stand Calibration: [A] 3		

	Correction Effective Date	WDK / WDN	TGF %	TLHC %	Transformed TLHC %	BSOC g/k W-h	EOTOC g/kW-h
Unadjusting Lab Rating		198.7	18	0	0.000	0.13	0.12
Industry Correction (if any)		0.0	0		-0.451	0.00	
Subtotal		198.7	18		-0.451	0.13	0.12
Lab Severity Adjustment (if any) [A]	20091205	0.0	0		0.835	0.00	
Total		198.7	18	1	0.384	0.13	0.12

	Effective Date	WDK / WDN	TGF %	TLHC %	Transformed TLHC %	BSOC g/k W-h	EOTOC g/kW-h
Test Target Mean [B]							
Test Target STD [B]							
CI-4 Pass Limits (First-Test) [A,C]		286.2	20.0	3.0		0.50	

	Referee Lab	WDK / WDN	TGF %
Referee Ratings			

	Top	Int. 1	Oil	Piston	Liner
Ring Loss of Side Clearance (mm)	0.047	0.012	0.000		
Ring End Gap Increase (mm)	0.000	0.025	0.000		
Is the Ring Stuck?	NO	NO	NO		
Scuffed Area %	0	0	0	0	0
Average Wear Step (mm)					0.020
% Bore Polish					7.0

Notes:
[A] *Non-reference tests only*
[B] *Reference tests only*
[C] *See Appendix X4*

1K/1N
Operational Summary
Form 2

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Operating Condition		Minimum	Maximum	Average	Specification
Engine Speed	r/min	2096.0	2107.0	2100.0	2100 ± 10
Engine Power	kW	46.7	50.2	49.4	Report
Fuel Flow	g/min	174.7	186.7	185.0	185 ±1
Humidity	g/kg	15.2	21.5	17.8	17.8 ± 1.7
Temperature °C					
Coolant Out	°C	92.8	93.2	93.0	93 ± 2.5
Coolant In	°C	86.7	87.3	87.0	Report
Coolant delta T	°C	5.7	6.2	6.0	5 ±1.0
Oil To BRG	°C	104.7	107.8	107.0	107 ± 2.5
Oil Cooler In	°C	105.9	109.9	109.4	Report
Inlet Air	°C	125.9	127.8	127.0	127 ± 2.5
Exhaust	°C	542.8	569.4	562.8	550 ± 30
Fuel @ Injector Housing	°C	54.5	60.2	57.2	57 ± 3
Pressures					
Oil to Bearing	kPa	386.8	404.7	399.2	482 Max
Oil to Jet	kPa	346.1	364.0	359.2	360 ± 13
Inlet Air	kPa	237.4	241.4	240.1	240 ± 1
Exhaust (ABS)	kPa	215.0	217.1	216.1	216 ±1
Fuel @ Filter HSG	kPa	184.1	214.4	211.7	210 ± 20
Crankcase Vacuum	kPa	-0.30	0.82	0.70	0.7 ± 0.1
Coolant Jug Pressure	kPa	57.2	61.4	58.6	Report
Flows					
Blowby	L/min	12.5	17.9	14.5	Report
Coolant Flow	L/min	63.0	65.2	64.8	65 ± 2

Air/Fuel Ratio 24 Hr:	28.0	Air/Fuel Ratio 252 Hr:	28.0

Assembly Measurement and Parts Record

Piston / Head Clearance mm:	3.632	Intake Valve Open °ATC:	2.0
		Fuel Flow Timing °BTC:	31.5

	Part No. (1)	Serial No. (2)	Date Code	Inspection Code
Liner	1Y3998	D12M08Y09P47	N/A [F]	N/A [G]
Ring Set (1)	1Y0728		231007A8871L [I]	A105 [H]
Piston	1Y0727	D19M01Y07P47	250107 (2) [D]	N/A [E]

[D] Number below "E" located on top of piston
[E] Number on top of "E" located on top of piston
[F] Four alphanumeric characters (NNAN) on liner O.D.
[G] Four digit number on liner O.D.
[H] Three or four digit number on white label on ring set box
[I] NN-NN from part number label on ring set box

(1) and (2) Number on Parts Box Yellow Label

1K/1N
Operational Summary - Offset and Deviation
Form 3

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Controlled Parameter	Allowable % Out	This Test % Out	Allowable % Off	This Test % Off
Speed	5	0.0	20	0.0
Fuel Flow	10	1.0	25	0.0
Humidity	10	1.2	25	0.4
Coolant Flow	5	0.0	25	5.0
Temperature				
Coolant Out	5	0.0	20	6.0
Oil to Bearing	5	0.0	20	4.0
Intake Air	5	0.0	20	6.0
Fuel at Injector Housing	5	0.0	20	2.8
Pressures				
Oil Jet	5	0.0	25	2.5
Intake Air	10	0.9	25	0.0
Exhaust	10	0.0	25	0.0
Fuel at Filter Housing	5	0.0	20	3.3
Crankcase Vacuum	10	2.5	20	1.3

1K/1N
Piston Rating Summary
Form 4

Test Identification	Lab: SR	EOT Date: 20100221	End Time: 04:16	Stand: 62	Run Number: 242	Method: 1N	Test Length: 252
Formulation / Stand Code:				Oil Code / CMIR:	MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900		
Test Fuel: JP-8	Fuel Batch:		Date Rated: 20100222	Rating Number:		Rater: RBV	

Last Stand Reference Information	Date Completed:	Stand Number: 62	Run Number:	TMC Oil Code:

	WDK / WDN	TGF	TLHC	Transformed TLHC	BSOC	EOTOC
Last Reference This Stand	0.0	0	0	0.000		
Industry Average						
Industry Std						

Total Piston Ratings Summary

		Grooves						Lands						Upper Skirt		Under Crown		Pin Bores			
	Dep. Factor	No. 1		No. 2		No. 3		No. 1		No. 2		No. 3						Front		Rear	
		A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.	A, %	Dem.
Carbon	HC-1.0			4	4.00					10	10.00										
	MC-0.5	21	10.50																		
	LC-.25	79	19.75	92	23.00			18	4.50	90	22.50	2	0.50								
	Total	100	30.25	96	27.00	0	0.00	18	4.50	100	32.50	2	0.50	0	0.00	0	0.00	0	0.00	0	0.00
Lacquer	8 - 9			2	0.18			2	0.18												
	7 - 7.9																				
	6 - 6.9																				
	5 - 5.9																				
	4 - 4.9																				
	3 - 3.9							5	0.18												
	2 - 2.9			2	0.05	3	0.07	24	0.53			4	0.09								
	1 - 1.9							10	0.10			20	0.30	23	0.23	30	0.33				
	>0 - 0.9					97	0.64	41	0.21			74	0.31	35	0.10	70	0.17	30	0.06	10	0.03
	Clean		0		0		0		0		0		0	42	0		0	70	0	90	0
	Total	0	0.00	4	0.23	100	0.71	82	1.20	0	0.00	98	0.70	100	0.33	100	0.50	100	0.06	100	0.03
Rating		30.25		27.23		0.71		5.70		32.50		1.20		0.33		0.50		0.06		0.03	
WDK LOC FCT		1.5		1.5		25		1		1		25		50		20		0		0	
Ind Rating		45.38		40.84		17.75		5.70		32.50		30.00		16.50		10.00		0.00		0.00	

TGF %	Int. GR. Fill %	WDK / WDN	Unweighted Dep.	T.L. Heavy Carbon %	T.L. Flaked Carbon %	ACC GR Fill %
18	23	198.7	98.5	0	0	41

1K/1N
Rating Worksheet

Method: 1N **Total Test Length:** 252

Test No.: 62-242 **Oil Code:** MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900 **Rater:** RBV **EOT Date:** 20100221

Grooves	No. 1			No. 2			No. 3			Undercrown			Upperskirt		
	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem
Carbon		1.0		4	1.0	4.00		1.0			1.0			1.0	
	21	.50	10.50					.50							
	79	.25	19.75	92	.25	23.00		.25			.25			.25	
	100	Sub T	30.25	96	Sub T	27.00	0	Sub T	0.00	0	Sub T	0.00	0	Sub T	0.00
Varnish		10-10.0		2	10-1.0	0.18	3	10-7.8	0.07	15	10-8.8	0.18	23	10-9.0	0.23
		10-10.0		2	10-7.5	0.05	60	10-9.2	0.48	15	10-9.0	0.15	10	10-9.5	0.05
		10-10.0			10-10.0		27	10-9.5	0.14	10	10-9.5	0.05	25	10-9.8	0.05
		10-10.0			10-10.0		10	10-9.8	0.02	30	10-9.7	0.09	42	10-10.0	
		10-10.0			10-10.0			10-10.0		30	10-9.9	0.03		10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
		10-10.0			10-10.0			10-10.0			10-			10-	
	0	Sub T	0.00	4	Sub T	0.23	100	Sub T	0.71	100	Sub T	0.50	100	Sub T	0.33
		Total	30.25		Total	27.23		Total	0.71		Total	0.50		Total	0.33

	Lands									Pin Bores					
	No. 1			No. 2			No. 3			Front			Rear		
	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem
Carbon		1.0		10	1.0	10.00		1.0			1.0			1.0	
	18	.25	4.50	90	.25	22.50	2	.25	0.50		.25			.25	
	18	Sub T	4.50	100	Sub T	32.50	2	Sub T	0.50	0	Sub T	0.00	0	Sub	0.00
Varnish	2	10-1.0	0.18		10-10.0		4	10-7.8	0.09	15	10-9.7	0.04	10	10-9.7	0.03
	5	10-6.5	0.18		10-10.0		10	10-8.2	0.18	15	10-9.9	0.02	90	10-10.0	
	24	10-7.8	0.53		10-10.0		10	10-8.8	0.12	70	10-10.0			10-10.0	
	10	10-9.0	0.10		10-10.0		15	10-9.3	0.10		10-10.0			10-10.0	
	11	10-9.2	0.09		10-10.0		15	10-9.5	0.08		10-10.0			10-10.0	
	30	10-9.6	0.12		10-10.0		44	10-9.7	0.13		10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
	82	Sub T	1.20	0	Sub T	0.00	98	Sub T	0.70	100	Sub T	0.06	100	Sub T	0.03
		Total	5.70		Total	32.50		Total	1.20		Total	0.06		Total	0.03

	Grooves			Lands			Upper Skirt	Under Crown	Pin Bores	
	1	2	3	1	2	3			Front	Rear
Rating	30.25	27.23	0.71	5.70	32.50	1.20	0.33	0.50	0.06	0.03
WDK LOC FCT	1.5	1.5	25	1	1	25	50	20	0	0
WT Rating	45.38	40.84	17.75	5.70	32.50	30.00	16.50	10.00	0.00	0.00

TGF: 18	Intermidate Groove Fill: 23	WDK / WDN: 198.7	Top Land Heavy Carbon: 0

1K/1N

Supplemental Piston Deposits (Groove Sides and Rings)

Form 5

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Deposit Type			Carbon			Varnish									
			HC	MC	LC	8 - 9	7 - 7.9	6 - 6.9	5 - 5.9	4 - 4.9	3 - 3.9	2 - 2.9	1 - 1.9	>0 - 0.9	Clean
Groove Top and Bottom	1	T			60	40									
		B				10		60		30					
	2	T			25	75									
		B							40	40	20				
	3	T										80	10	10	
		B										40	40	20	
Top Bottom and Back of Rings	1	T			15	20					20	25	20		
		B											100		
		BK			100										
	2	T			5	10					20	40	25		
		B				5						20	75		
		BK			100										
	3	T										15	85		
		B										10	10	80	
		BK										50	50		

Additional Deposit & Condition Ratings	
Piston Crown	Normal.
Liner	Normal.
Rings	Normal.

1K/1N
Oil Analysis and Results Summary
Form 6

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			
Test Method: 1N	**Test Fuel:**	**Fuel Batch:**	

Oil Analysis / Engine Hours	NEW / 0	24	204	252
Viscosity @ 100°C	10.26	9.64	9.70	9.83
TBN D4739	10.19	9.20	7.06	6.11

Wear Metals: Fe / Al	2	1	10	1	31	2	36	2
Si / Cu	6	<1	5	<1	8	2	8	2
Cr / Pb	<1	<1	<1	2	<1	2	<1	2
Fuel Dilution %			0.3		0.3		0.3	
Blowby (L/min)			14.2		14.6		15.6	

24 Hour Average BSOC (g/w-W-h) for Hours End				0-252 Hr. Avg. BSOC (g/k-W-h): 0.13		EOT Oil Consumption(g/kW-h): 0.12			
24	48	72	108	132	156	180	204	228	252
0.20	0.10	0.11	0.12	0.18	0.12	0.12	0.13	0.15	0.17

Inspection and Measurement Summary	**Ring Gap Increase (mm)**	**Side Clearance Loss (mm)**	**Ring Stuck (1)**	**Scuffed Area % (2)**	**% Bore Polish (With Grid)**	**Average Wear Step (mm)**
Top Ring	0.000	0.047	NO	0		
Intermediate Ring	0.025	0.012	NO	0		
Oil Ring	0.000	0.000	NO	0		
Piston				0		
Cylinder Liner				0	7.0	0.020

Piston Deposit Summary	TGF %	Int. Gr. F.%	WDK	Un Wt Dep	T.L. Heavy Carbon	T.L. Flaked Carbon %
	18	23	198.7	98.5	0	0

Unweighted Piston Deposits

Grooves			**Lands**			**Upper Skirt**	**Under Crown**	**Pin Bores**	
1	2	3	1	2	3			Front	Rear
30.25	27.23	0.71	5.70	32.50	1.20	0.33	0.50	0.06	0.03

1K/1N
Unscheduled Downtime & Maintenance Summary
Form 7

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Number of Downtime Occurrences: 0

Test	Date	Downtime	Reasons
Total Downtime			

Other Comments

Number of Comment Lines: 2

Due to the use of JP-8 fuel instead of the offical PC-9
fuel, this test was determined to be non interpretable.

1K/1N
Ring Measurements
Form 8

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Ring Gaps (mm)	Top	Intermediate	OIL
Specifications	0.724 ± 0.076 mm	0.673 ± 0.076 mm	0.572 ± 0.190 mm
Pre-Test	0.737	0.635	0.508
Post-Test	0.737	0.660	0.508
Increase	0.000	0.025	0.000

Ring Side Clearance *		A	B	C	D	Average	Minimum	Specification
Top	Pre-Test	0.203	0.203	0.190	0.190	0.196	0.190	0.193±0.032 mm
	Post-Test	0.178	0.178	0.089	0.152	0.149	0.089	
	LSC	0.025	0.025	0.101	0.038	0.047	0.025	
Intermediate	Pre-Test	0.076	0.076	0.076	0.076	0.076	0.076	0.090±0.020 mm
	Post-Test	0.064	0.064	0.064	0.064	0.064	0.064	
	LSC	0.012	0.012	0.012	0.012	0.012	0.012	
Oil	Pre-Test	0.064	0.064	0.064	0.064	0.064	0.064	0.073 ±0.016 mm
	Post-Test	0.064	0.064	0.064	0.064	0.064	0.064	
	LSC	0.000	0.000	0.000	0.000	0.000	0.000	

* Notes:

1. Write "Stuck" In Place of Dimension When Applicable.

2. Write "<0.038 mm" For Clearance When Applicable.

3. Write ">" Before Calculated Decrease or Average Decrease Values That Incorporate a "<0.038 mm" in Calculation.

4 LSC: Loss of Clearance.

5. Minimum: Intermediate and Oil Ring Minimum Side Clearance is Measured 360° Around Piston.

1K/1N
Liner Measurements
Form 9

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Liner Surface Finish (micrometer)			
Distance From Top	**Transverse**	**Longitudinal**	**Average**
130 mm			
50 mm			
25 mm			
		Total Average:	

% Liner Bore Polish - Grid (Add T/AT Values From Grid)	
Thrust	3.0
Anti-Thrust	4.0
Total	7.0

Liner Bore Measurement (mm)		
Before Test - Diameter (Dial Bore Gage)		
Bore Height	**Longitudinal**	**Transverse**
230 mm	137.155	137.190
130 mm	137.157	137.196
50 mm	137.160	137.196
25 mm	137.168	137.203
15 mm	137.165	137.198

After Test - (Surface Profile)				
	Longitudinal		**Transverse**	
	Front	Rear	T	AT
Wear Step @ 15mm	0.020	0.020	0.020	0.020

1K/1N
Characteristics of the Data Acquisition System
Form 10

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Parameter (1)	Sensing Device (2)	Calibration Frequency (3)	Record Device (4)	Observation Frequency (5)	Record Frequency (6)	Log Frequency (7)	System Response (8)
Operation Conditions							
Engine Speed (r/min)	Magnetic Pickup	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.1
Engine Power (kW)	Load Cell	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	1.9
Fuel Flow (kJ/min)	Micro-Motion	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	70.3
Humidity (g/kg)	Dew Cell	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	6.0 min
Temperatures (°C)							
Coolant Out	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Coolant In	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.7
Oil to Bearing	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Oil Cooler In	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Inlet Air	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Exhaust	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Pressure (kPa)							
Oil to Bearing	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Oil to Jet	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.0
Inlet Air	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	1.0
Exhaust	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Fuel @ Filter HSG	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Crankcase Vacuum	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Flows (L/min)							
Blowby	Gas Meter	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	10.0
Coolant Flow	Barco Venturi	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0

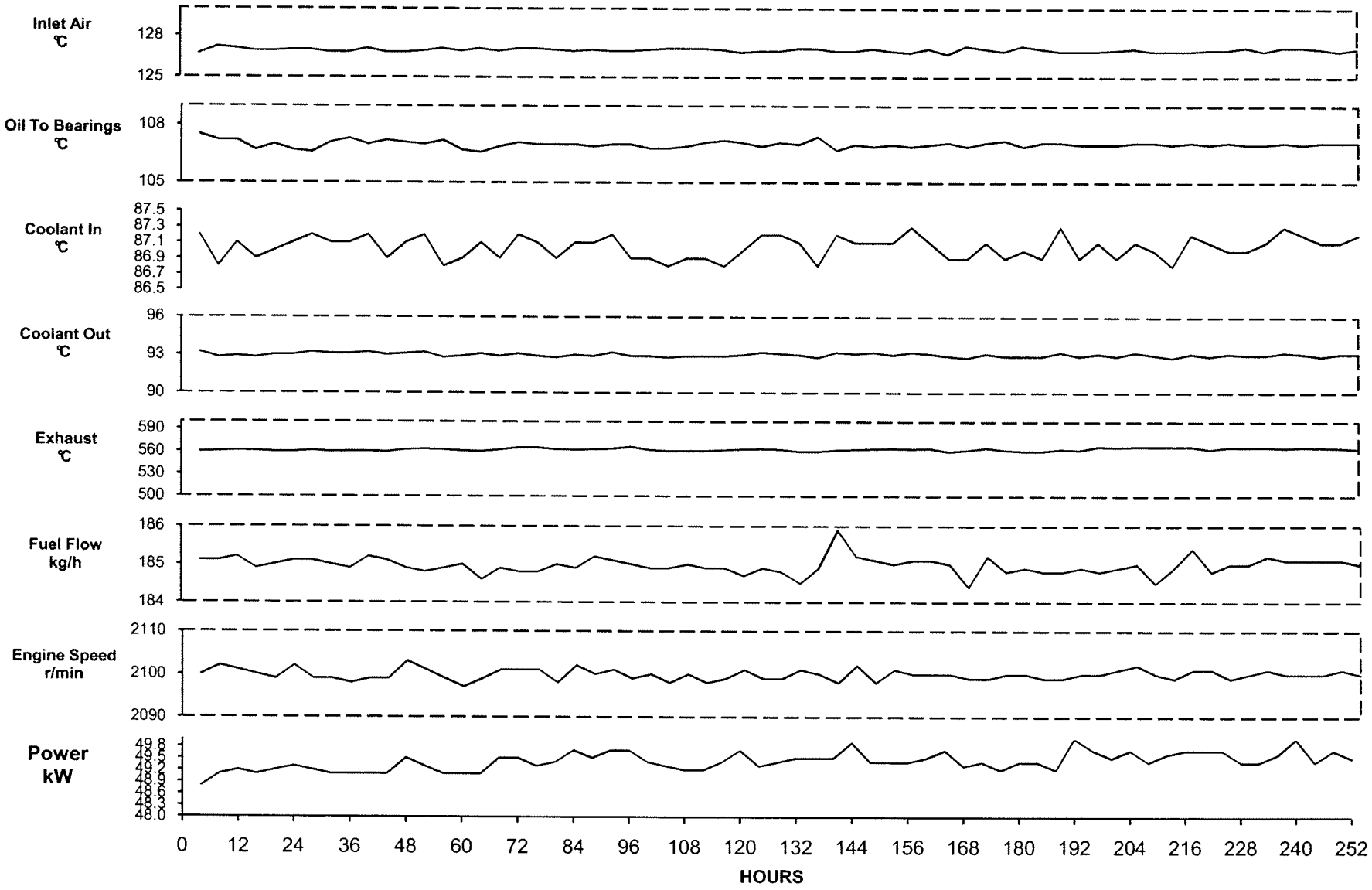
Legend:
(1) Operating Parameter
(2) The Type of Device Used to Measure Temperature, Pressure, or Flow
(3) Frequency at Which the Measurement System is Calibrated
(4) The Type of Device Where Data is Recorded
- LG - Hanglog Sheet
- DL - Automatic Data Logger
- SC - Strip Chart Recorder
- C/M - Computer, Using Manual Data Entry
- C/D - Computer, Using Direct I/O Entry

(5) Data Area Observed but Only Recorded if off Spec.
(6) Data are Recorded but are not Retained at EOT
(7) Data are Logged as Permanent Record, Note Specify if:
- SS - Snapshot Taken at Specified Frequency
- AG/X - Average of X Data Points at Specified Frequency

(8) Time for the Output to Reach 63.2% of Final Value for Step Change at Input

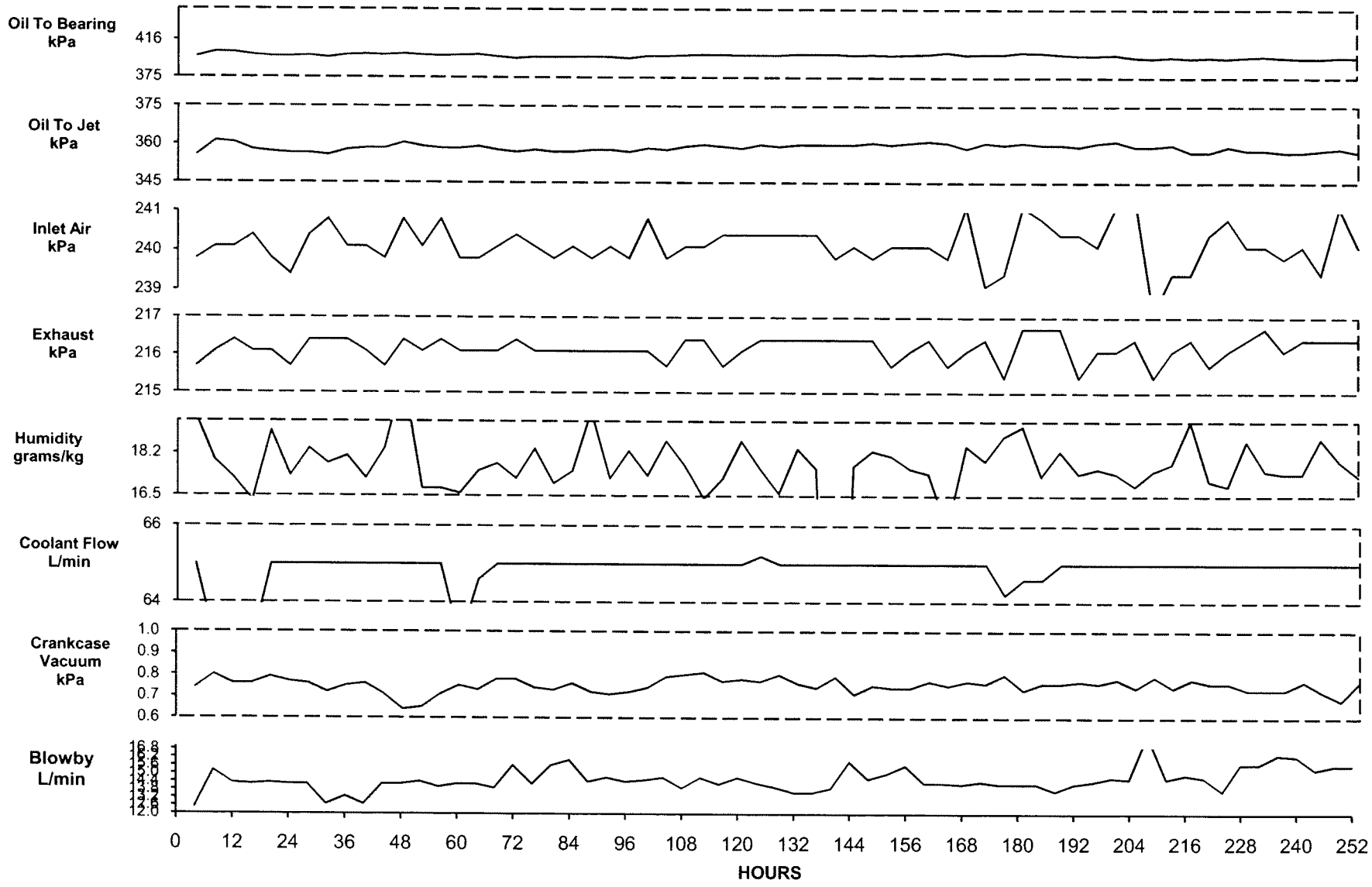
1K/1N
Form 11

Laboratory: SR	EOT Date: 20100221	EOT Time: 04:16	METHOD: 1N
TEST NUMBER			
STAND: 62	RUN NUMBER: 242		
FORMULATION/STAND CODE:			
OIL CODE:	MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900		



1K/1N
Form 12

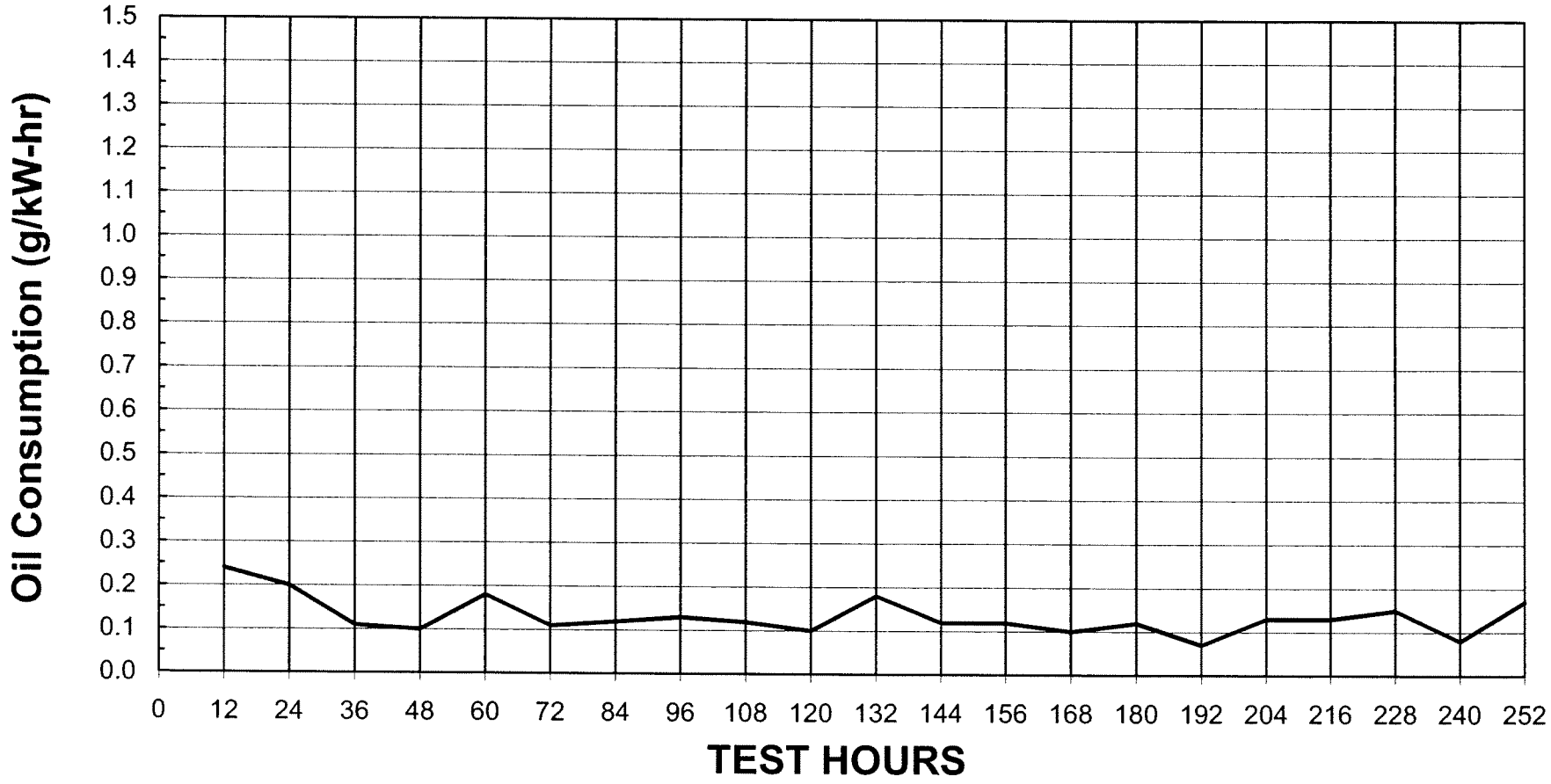
Laboratory: SR	EOT Date: 20100221	EOT Time: 04:16	METHOD: 1N
TEST NUMBER			
STAND: 62	RUN NUMBER: 242		
FORMULATION/STAND CODE:			
OIL CODE:	MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900		



1K/1N
Form 13
Oil Consumption Plot

Laboratory: SR	EOT Date: 20100221	EOT Time: 04:16	METHOD: 1N
TEST NUMBER			
STAND: 62	RUN NUMBER: 242		
FORMULATION/STAND CODE:			
OIL CODE:	MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900		

0 - 24 Hour	0.22	
228 - 252 Hour	0.13	
Avg 0 - 252 Hour	0.13	
Increase 0 - 24 to 228 - 252 Hour	-0.10	(-43.18%)



1K/1N
Severity Adjustment History
Form 15

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Usage Dates		WDK/WDN		TGF %		Transformed TLHC %	
Start	Time	Zi	S.A.	Zi	S.A.	Zi	S.A.
20091205	07:45	-0.059	0.0	-0.345	0	-0.928	0.000
20090920	07:17	0.018	0.0	-0.294	0	-1.056	0.950
20081019	09:18	-0.017	0.0	-0.266	0	-0.980	0.882
20080528	19:52	-0.037	0.0	-0.300	0	-0.828	0.745
20070925	10:13	0.199	0.0	-0.286	0	-0.695	0.625
20070110	02:31	0.071	0.0	-0.234	0	-0.528	0.000
20060114	06:11	0.092	0.0	-0.191	0	-0.263	0.000
20051118	11:31	-0.574	0.0	-0.130	0	-0.418	0.000
20041117	01:41	-0.459	0.0	-0.175	0	-0.462	0.000
20040314	16:27	-0.620	0.0	-0.066	0	-0.762	0.686
20040125	10:40	-0.248	0.0	0.121	0	-0.561	0.000
20040121	21:21	-0.279	0.0	-0.259	0	-0.549	0.000
20030125	18:08	-0.461	0.0	-0.094	0	-0.377	0.000
20020922	19:14	-0.432	0.0	-0.037	0	-0.318	0.000
20010926	02:07	-0.273	0.0	-0.061	0	-0.246	0.000
20010922	09:52	-0.208	0.0	-0.249	0	-0.155	0.000
20010814	21:55	-0.242	0.0	-0.275	0	-0.041	0.000
20010803	21:55	-0.242	0.0	-0.275	0	-0.041	0.000
20010723	01:52	-0.503	0.0	-0.126	0	-0.357	0.000
20010214	10:06	-0.289	0.0	0.162	0	-0.294	0.000
20000925	03:50	-0.128	0.0	0.059	0	-0.215	0.000
19990929	01:16	-0.212	0.0	0.314	0	-0.413	0.000
19981004	15:37	0.002	0.0	0.258	0	-0.262	0.000
19980520	03.44	0.108	0.0	0.343	0	-0.175	0.000
19971110	10:30	0.183	0.0	0.041	0	-0.022	0.000
19971103	14:25	0.338	0.0	0.114	0	-0.179	0.000

Lab: SR	**EOT Date:** 20100221	**END Time:** 04:16	**Method:** 1N
Stand: 62	**Run Number:** 242	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: MIL-PRF-46167D ARCTIC ARPOLUBE LOT#900			

Appendix

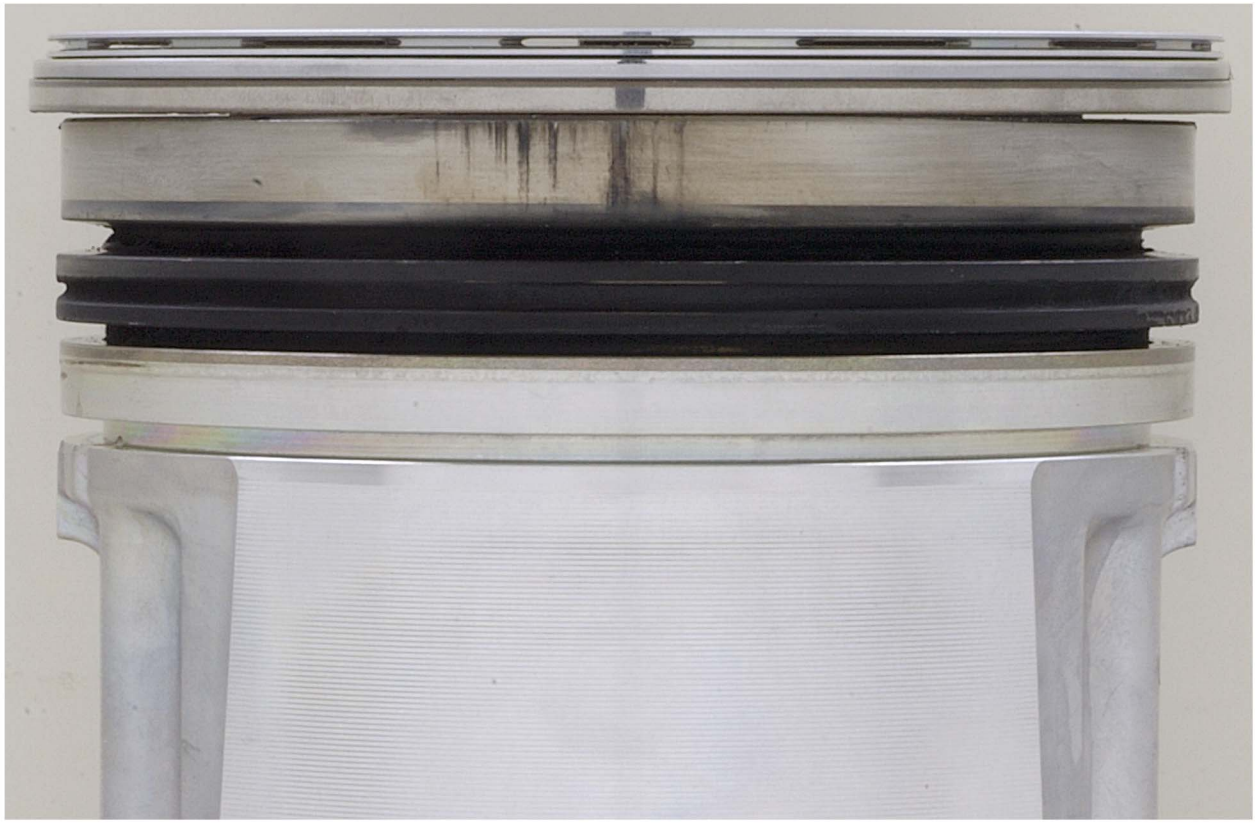
Photographs

1. Piston (Thrust and Anti-Thrust)
2. Pin Bores (Front and Rear)
3. Undercrown
4. Liner (Thrust and Anti-Thrust)

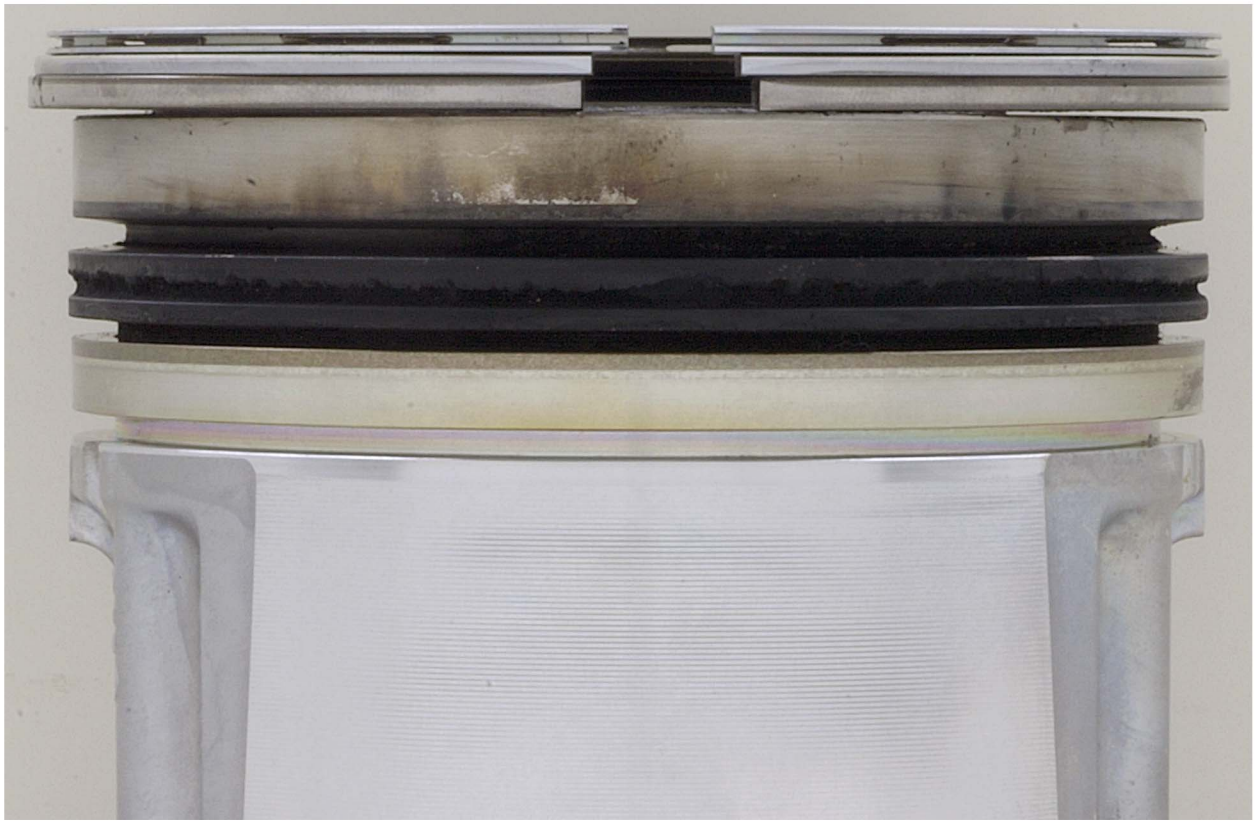
Caterpillar 1N

Laboratory:	SR	**Oil Code:**	MIL-PRF-46167D
Completion Date:	02/21/10	**Test No.:**	62-242
Formulation / Stand Code:		**Test Hours:**	252

Piston Thrust



Piston Anti-Thrust



Caterpillar 1N

Laboratory:	SR	**Oil Code:**	MIL-PRF-46167D
Completion Date:	02/21/10	**Test No.:**	62-242
Formulation / Stand Code:		**Test Hours:**	252

Pinbores

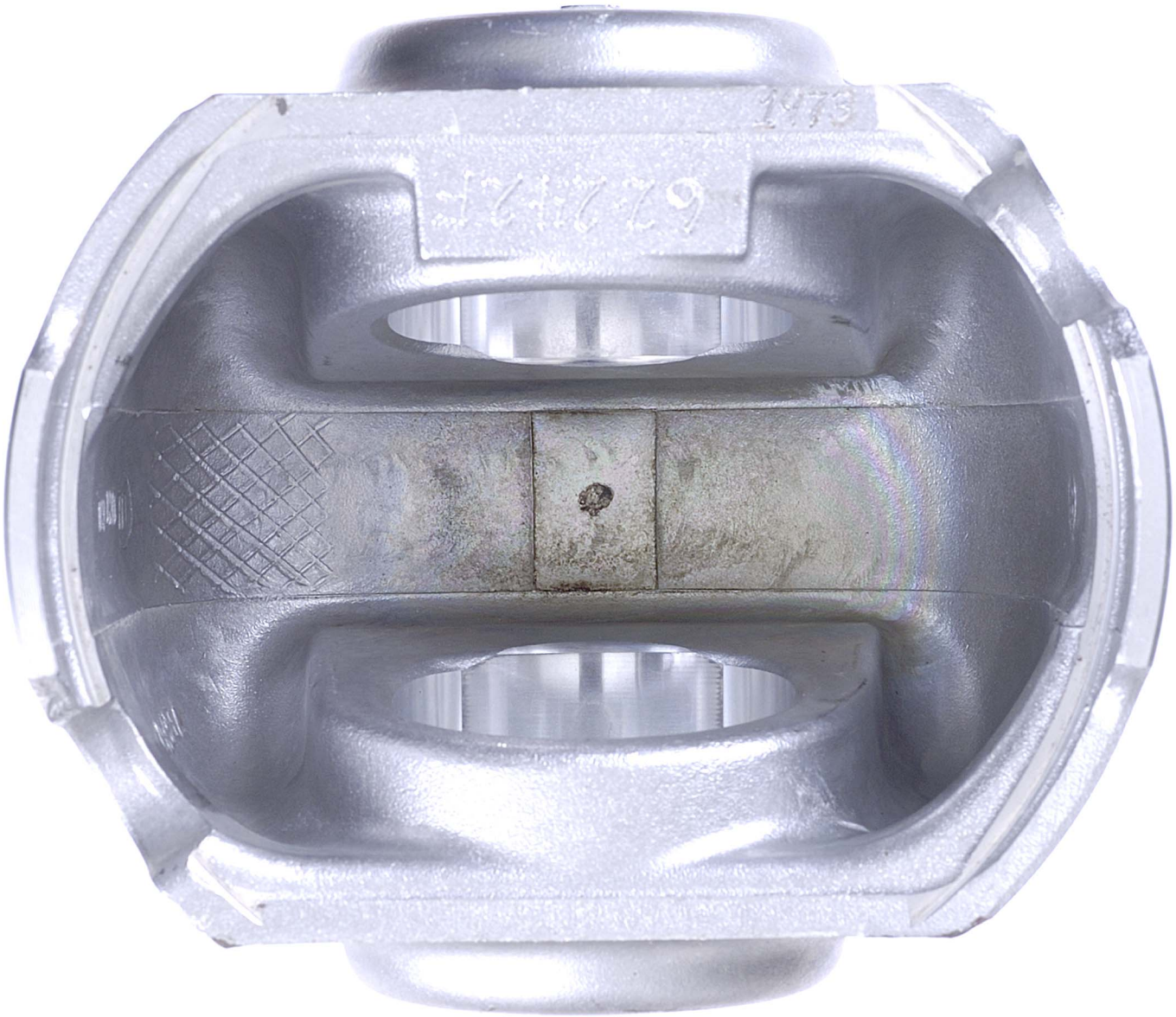
Front

Rear

Caterpillar 1N

Laboratory:	SR	**Oil Code:**	MIL-PRF-46167D		
Completion Date:	02/21/10	**Test No.:**	62-242		
Formulation / Stand Code:				**Test Hours:**	252

Undercrown

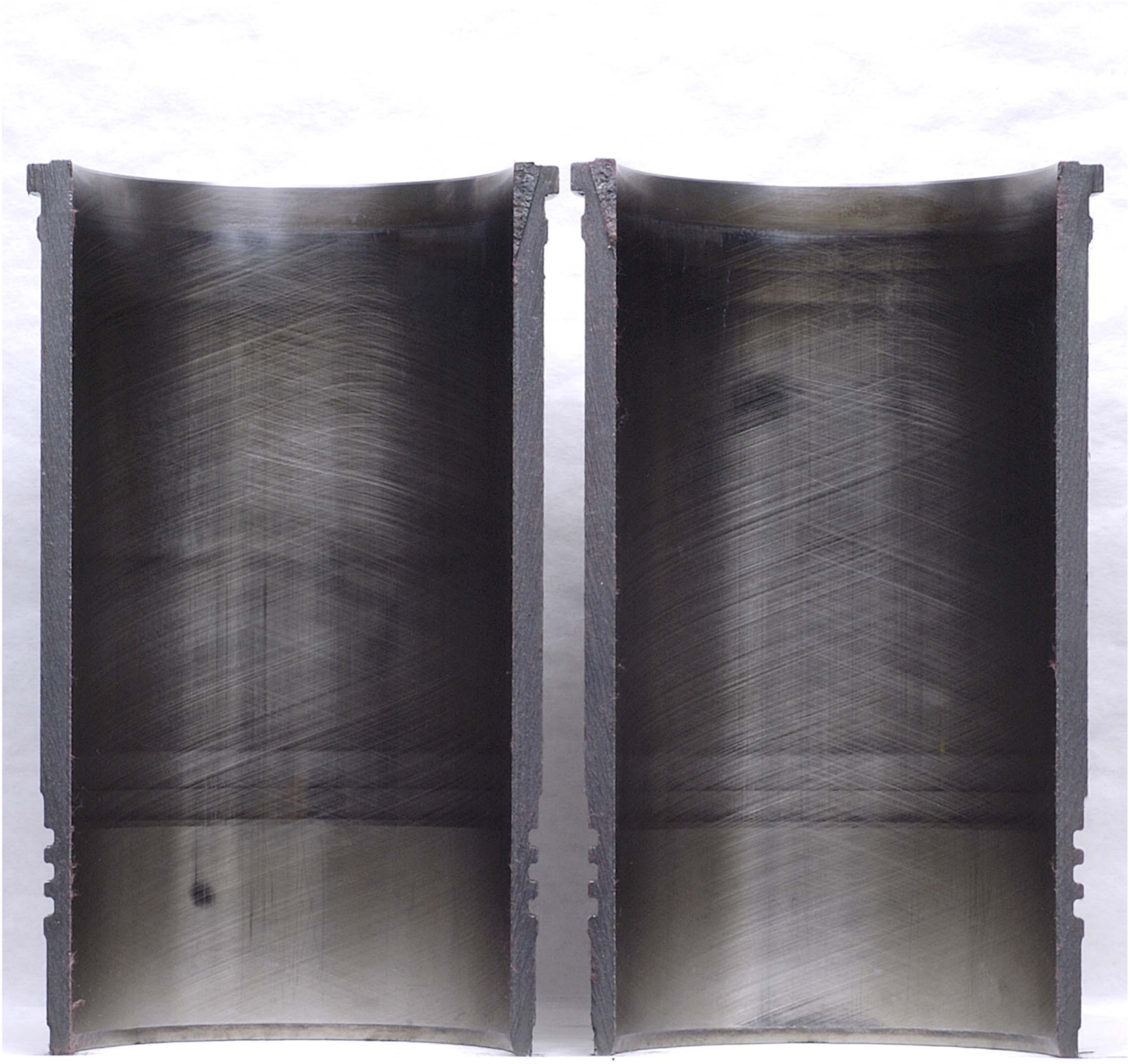


Caterpillar 1N

Laboratory:	SR	**Oil Code:**	MIL-PRF-46167D
Completion Date:	02/21/10	**Test No.:**	62-242
Formulation / Stand Code:		**Test Hours:**	252

Liner

Thrust **Anti-Thrust**



End of Report

At

This Point

Remaining Documentation is Back-up

A- C11200

Index #: 17462

Scanned: 3/3/10

Photos Merged: 3/3/10

QA Check: _____

Purge JPEGs: _____

Fri Feb 26 15:25:06 **REPRINT** *Hot Date* _____

PROJECT # 1.08.03 08812.209
SPONSOR Southwest Research Institute
SPONSOR BILLED Southwest Research Institute
PRIMARY SPONSOR CODE MIL-PRF-46167D
SECONDARY SPONSOR CODE ARTIC ARPOLUBE
MISCELLANEOUS CODE
AUTH: ☐ T/A
☐ TWX DATE
☐ PO#/TK#

TEST TYPE Caterpillar 1N
SwRI CODE 247699
TEST# 62-242
START DATE 02/10/10 EOT DATE 02/21/10
HOURS 252 CYCLES MILES
OPERATIONAL DATA: ☐ PASS ☐ FAIL ☒ VALID ☐ INVALID ☐ ABORT ☐ TERMINATED ☐ NO TEST ☐ RERUN

REPORTING

3 Reports/Forms 3 Photos D/C r/s d/s to ROBERT WARDEN at ARMY LAB in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in
___ Reports/Forms ___ Photos D/C r/s d/s to ___ at ___ in

RESULTS SENT 13:44

SHIPPING

Parts/Report To:
Samples/ To:
Brg wt loss: top bottom total Are parts/samples in storage?
STORE: Parts YES Samples YES Final Drn YES DUMP: Parts 02/11 Samples 02/11 Final Drn 02/11
Additional information or special instructions:

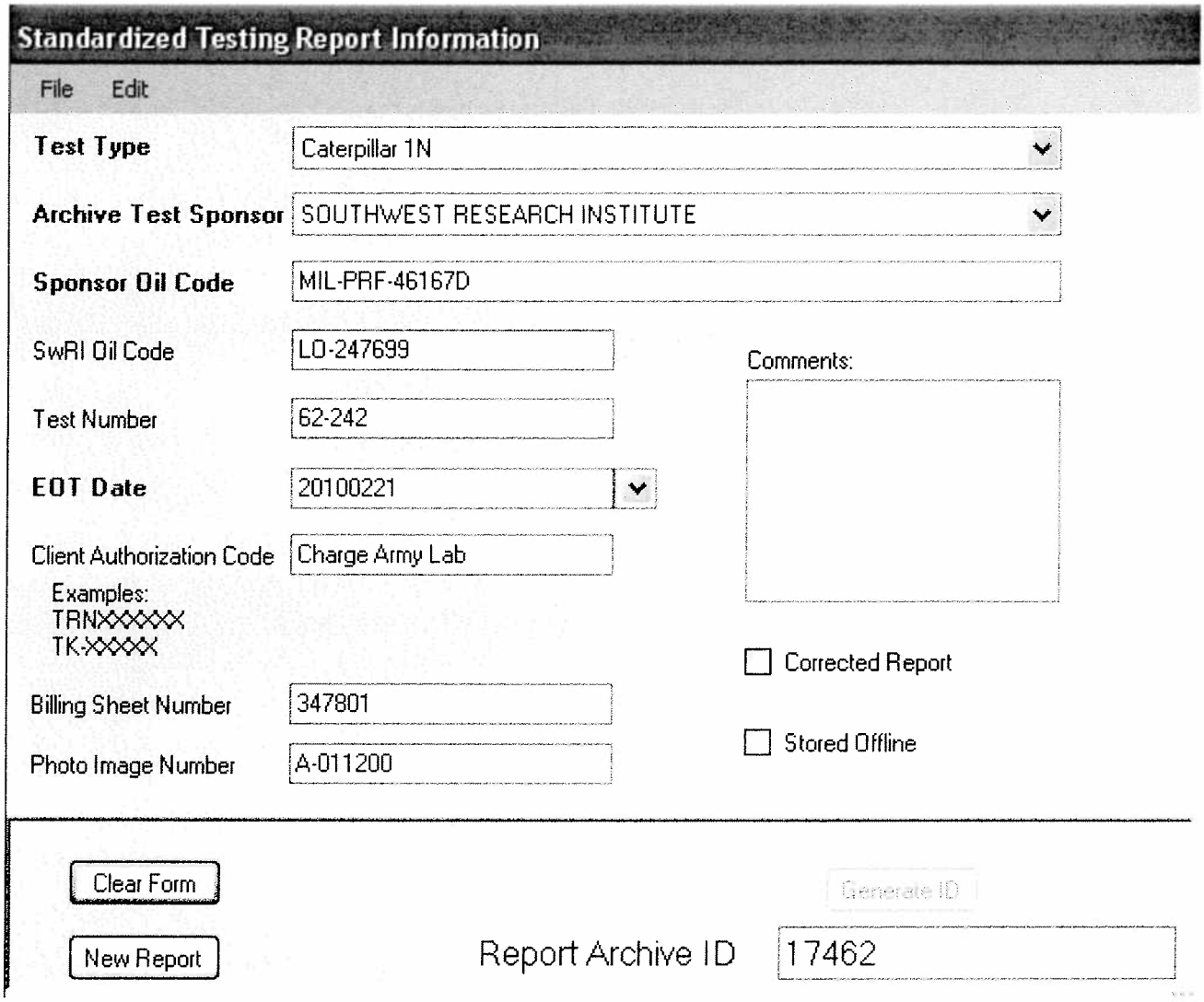
BILLING

FOR BILLING PURPOSES ONLY ☐ **VIP Client** ☐ **TSV Applies**

1. Base Cost of Test (includes 3 reports/forms w/o photos)		$
2. ASTM Escrow Fund Fee (if applicable)		
3. Photographs	___ sets at ___ ea ___	
4. Digital Capture	___ sets at ___ ea ___	
5. Rating Work Sheets	___ sets at ___ ea ___	
6. Data Sheets	___ sets at ___ ea ___	
7. Additional Photographs	___ sets at ___ ea ___	
8. Additional Forms	___ sets at ___ ea ___	
9. Additional Reports	___ sets at ___ ea ___	
10. Items 8 & 9 (if in storage) Additional charge at $ ___ ea ___		
11. Inspections (specify) ___ hr intermediate at $ ___ ea ___		
12. Analysis: ___ ( )		
13. Extra Page Total		
14. Metal Examination of Cooler Fittings ( )		
15. Miscellaneous CHARGE TO ARMY LAB PROJ: 14734.10.300 ($18,720.00)		
16. Miscellaneous Credit		
	SUBTOTAL $	0.00
17. Rebate		
18 CREDIT (VIP)		
19 CREDIT (TSV)		

ORIGINATOR'S NAME G Hammer Date 02/26/10 Total Test Cost $ 0.00

NO: 347801 **DEPARTMENT**


Standardized Testing Report Information
File
Edit
Test Type
Caterpillar 1N
Archive Test Sponsor
SOUTHWEST RESEARCH INSTITUTE
Sponsor Oil Code
MIL-PRF-46167D
SwRI Oil Code
LO-247699
Test Number
62-242
EOT Date
20100221
Client Authorization Code
Charge Army Lab
Examples:
TRNXXXXXX
TKXXXXX
Billing Sheet Number
347801
Photo Image Number
A-011200
Comments:
Corrected Report
Stored Offline
Clear Form
New Report
Generate ID
Report Archive ID
17462

1K/1N

Version 20090901

Title / Validity Declaration Page

Method 1N

Conducted for

SOUTHWEST RESEARCH INSTITUTE

N	V = Valid
	I = Invalid
	N = Results cannot be Interpreted as Respresentative of Oil Performance (Non-Reference Oil) and shall not be used for Multiple Test Acceptance Criteria
NR	RO = Reference Oil Test
	NR = All Other Tests
Y	Was This Test Run Under a Valid Calibration? (Y/N)
	Lab is Currently Operating Under an LTMS Precision Alarm *
	Stand is Currently Operating Under an LTMS Precision Alarm *

** Check box only if YES*

Test Number		
Test Stand: 62	**Engine Run No.:** 243	
EOT Time: 10:21	**EOT Date:** 20100307	
Oil Code ** ARMY LAB WD10 ADDITIVE LUBRICANT		
Formulation / Stand Code: A		
Alternate Codes: B		

In my opinion this test has not been conducted in a valid manner in accordance with ASTM Test Method D 6750 (1K/1N) and the appropriate amendments through the information letter system. The remarks included in the report describe the anomalies associated with this test.

The results of this report relate only to the items tested.

***CMIR or Non-Reference Oil Code*

A ACC -Registered Tests Only

B When Provided or Required by Client

Submitted by:

Southwest Research Institute (R)

Testing Laboratory

Signature

James F. McCord

Typed Name

Senior Research Engineer

Title

1K/1N
Test Report Summary
Form 1

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243		
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Start Date: 20100224	Total Test Length: 252	TMC Oil Type:
Laboratory Internal Oil Code: LO-248598		
Number of Test Starts Since Stand Calibration: [A]		

	Correction Effective Date	WDK / WDN	TGF %	TLHC %	Transformed TLHC %	BSOC g/k W-h	EOTOC g/kW-h
Unadjusting Lab Rating		159.1	7	0	0.000	0.13	0.10
Industry Correction (if any)		0.0	0		-0.451	0.00	
Subtotal		159.1	7		-0.451	0.13	0.10
Lab Severity Adjustment (if any) [A]	20091205	0.0	0		0.835	0.00	
Total		159.1	7	1	0.384	0.13	0.10

	Effective Date	WDK / WDN	TGF %	TLHC %	Transformed TLHC %	BSOC g/k W-h	EOTOC g/kW-h
Test Target Mean [B]							
Test Target STD [B]							
CI-4 Pass Limits (First-Test) [A,C]		286.2	20.0	3.0		0.50	

	Referee Lab	WDK / WDN	TGF %
Referee Ratings			

	Top	Int. 1	Oil	Piston	Liner
Ring Loss of Side Clearance (mm)	0.035	0.061	0.000		
Ring End Gap Increase (mm)	0.026	0.025	0.000		
Is the Ring Stuck?	NO	NO	NO		
Scuffed Area %	0	0	0	0	0
Average Wear Step (mm)					0.022
% Bore Polish					7.0

Notes:
[A] *Non-reference tests only*
[B] *Reference tests only*
[C] *See Appendix X4*

1K/1N
Operational Summary
Form 2

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Operating Condition		Minimum	Maximum	Average	Specification
Engine Speed	r/min	2091.0	2109.0	2100.0	2100 ± 10
Engine Power	kW	47.0	50.5	49.6	Report
Fuel Flow	g/min	175.2	187.0	185.0	185 ±1
Humidity	g/kg	11.4	21.4	17.8	17.8 ± 1.7
Temperature °C					
Coolant Out	°C	92.8	93.3	93.0	93 ± 2.5
Coolant In	°C	87.6	88.3	88.0	Report
Coolant delta T	°C	4.9	5.2	5.0	5 ±1.0
Oil To BRG	°C	105.1	109.3	107.0	107 ± 2.5
Oil Cooler In	°C	107.9	109.8	109.3	Report
Inlet Air	°C	126.5	127.7	127.0	127 ± 2.5
Exhaust	°C	534.4	562.2	556.7	550 ± 30
Fuel @ Injector Housing	°C	53.9	61.9	57.3	57 ± 3
Pressures					
Oil to Bearing	kPa	393.0	404.0	398.5	482 Max
Oil to Jet	kPa	354.4	364.7	359.2	360 ± 13
Inlet Air	kPa	239.8	240.4	240.1	240 ± 1
Exhaust (ABS)	kPa	215.4	217.1	216.1	216 ±1
Fuel @ Filter HSG	kPa	206.8	214.4	211.7	210 ± 20
Crankcase Vacuum	kPa	0.48	0.89	0.69	0.7 ± 0.1
Coolant Jug Pressure	kPa	56.5	60.0	58.6	Report
Flows					
Blowby	L/min	12.0	16.2	14.2	Report
Coolant Flow	L/min	65.0	65.2	65.0	65 ± 2

Air/Fuel Ratio 24 Hr:	28.0	Air/Fuel Ratio 252 Hr:	28.0
Assembly Measurement and Parts Record			
Piston / Head Clearance mm:	3.607	Intake Valve Open °ATC:	2.0
		Fuel Flow Timing °BTC:	31.5

	Part No. (1)	Serial No. (2)	Date Code	Inspection Code
Liner	1Y3998	D07M06Y05P47	N/A [F]	1250 [G]
Ring Set (1)	1Y0728		22090BA8871L [I]	A130 [H]
Piston	1Y0727	D19M01Y07P47	25 0107 (2) [D]	N/A [E]

[D] Number below "E" located on top of piston
[E] Number on top of "E" located on top of piston
[F] Four alphanumeric characters (NNAN) on liner O.D.
[G] Four digit number on liner O.D.
[H] Three or four digit number on white label on ring set box
[I] NN-NN from part number label on ring set box

(1) and (2) Number on Parts Box Yellow Label

1K/1N
Operational Summary - Offset and Deviation
Form 3

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Controlled Parameter	Allowable % Out	This Test % Out	Allowable % Off	This Test % Off
Speed	5	0.0	20	0.0
Fuel Flow	10	0.9	25	0.0
Humidity	10	0.8	25	0.8
Coolant Flow	5	0.0	25	0.0
Temperature				
Coolant Out	5	0.0	20	6.0
Oil to Bearing	5	0.0	20	4.0
Intake Air	5	0.0	20	6.0
Fuel at Injector Housing	5	1.4	20	5.6
Pressures				
Oil Jet	5	0.0	25	2.5
Intake Air	10	0.0	25	0.0
Exhaust	10	0.0	25	0.0
Fuel at Filter Housing	5	0.0	20	3.3
Crankcase Vacuum	10	8.8	20	1.3

1K/1N
Piston Rating Summary
Form 4

Test Identification	Lab: SR	EOT Date: 20100307	End Time: 10:21	Stand: 62	Run Number: 243	Method: 1N	Test Length: 252
Formulation / Stand Code:				Oil Code / CMIR:	ARMY LAB WD10 ADDITIVE LUBRICANT		
Test Fuel: JP-8	Fuel Batch:		Date Rated: 20100308	Rating Number:		Rater: RBV	

Last Stand Reference Information	Date Completed: 20090920	Stand Number: 62	Run Number: 235	TMC Oil Code: 809-1

	WDK / WDN	TGF	TLHC	Transformed TLHC	BSOC	EOTOC
Last Reference This Stand	210.4	27	0	0.000	0.19	0.20
Industry Average	205.0	35.3		1.197	0.31	
Industry Std	34.6	20.5		1.200	0.17	

Total Piston Ratings Summary

	Dep. Factor	Grooves No. 1 A, %	Grooves No. 1 Dem.	Grooves No. 2 A, %	Grooves No. 2 Dem.	Grooves No. 3 A, %	Grooves No. 3 Dem.	Lands No. 1 A, %	Lands No. 1 Dem.	Lands No. 2 A, %	Lands No. 2 Dem.	Lands No. 3 A, %	Lands No. 3 Dem.	Upper Skirt A, %	Upper Skirt Dem.	Under Crown A, %	Under Crown Dem.	Pin Bores Front A, %	Pin Bores Front Dem.	Pin Bores Rear A, %	Pin Bores Rear Dem.
Carbon	HC-1.0									30	30.00										
	MC-0.5	5	2.50																		
	LC-.25	95	23.75	25	6.25			20	5.00	68	17.00										
	Total	100	26.25	25	6.25	0	0.00	20	5.00	98	47.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Lacquer	8 - 9			3	0.27											2	0.18				
	7 - 7.9																				
	6 - 6.9																				
	5 - 5.9															3	0.17				
	4 - 4.9																				
	3 - 3.9																				
	2 - 2.9			15	0.30			13	0.33	2	0.06					15	0.34				
	1 - 1.9			10	0.10							5	0.09			20	0.30				
	>0 - 0.9			47	0.28	100	0.42	67	0.10			95	0.40	45	0.17	60	0.27				
	Clean		0		0		0		0		0		0	55	0		0	100	0	100	0
	Total	0	0.00	75	0.95	100	0.42	80	0.43	2	0.06	100	0.49	100	0.17	100	1.26	100	0.00	100	0.00
Rating		26.25		7.20		0.42		5.43		47.06		0.49		0.17		1.26		0.00		0.00	
WDK LOC FCT		1.5		1.5		25		1		1		25		50		20		0		0	
Ind Rating		39.38		10.80		10.50		5.43		47.06		12.25		8.50		25.20		0.00		0.00	

TGF %	Int. GR. Fill %	WDK / WDN	Unweighted Dep.	T.L. Heavy Carbon %	T.L. Flaked Carbon %	ACC GR Fill %
7	3	159.1	88.3	0	0	49

1K/1N
Rating Worksheet

Method: 1N **Total Test Length:** 252

Test No.: 62-243 **Oil Code:** ARMY LAB WD10 ADDITIVE LUBRICANT **Rater:** RBV **EOT Date:** 20100307

Grooves

	No. 1			No. 2			No. 3			Undercrown			Upperskirt		
	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem
Carbon		1.0			1.0			1.0			1.0			1.0	
	5	.50	2.50					.50							
	95	.25	23.75	25	.25	6.25		.25			.25			.25	
	100	Sub T	26.25	25	Sub T	6.25	0	Sub T	0.00	0	Sub T	0.00	0	Sub T	0.00
Varnish		10-10.0		3	10-1.0	0.27	20	10-9.2	0.16	2	10-1.0	0.18	20	10-9.5	0.10
		10-10.0		15	10-8.0	0.30	25	10-9.5	0.12	3	10-4.5	0.17	20	10-9.7	0.06
		10-10.0		10	10-9.0	0.10	25	10-9.7	0.08	15	10-7.7	0.34	5	10-9.9	0.01
		10-10.0		18	10-9.2	0.14	30	10-9.8	0.06	10	10-8.2	0.18	55	10-10.0	
		10-10.0		29	10-9.5	0.14		10-10.0		10	10-8.8	0.12		10-10.0	
		10-10.0			10-10.0			10-10.0		30	10-9.2	0.24		10-10.0	
		10-10.0			10-10.0			10-10.0		30	10-9.9	0.03		10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
	0	Sub T	0.00	75	Sub T	0.95	100	Sub T	0.42	100	Sub T	1.26	100	Sub T	0.17
		Total	26.25		Total	7.20		Total	0.42		Total	1.26		Total	0.17

Lands / Pin Bores

	Lands No. 1			Lands No. 2			Lands No. 3			Pin Bores Front			Pin Bores Rear		
	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem	A%	FCT	Dem
Carbon		1.0		30	1.0	30.00		1.0			1.0			1.0	
	20	.25	5.00	68	.25	17.00		.25			.25			.25	
	20	Sub T	5.00	98	Sub T	47.00	0	Sub T	0.00	0	Sub T	0.00	0	Sub	0.00
Varnish	9	10-7.2	0.25	2	10-7.2	0.06	5	10-8.2	0.09	100	10-10.0		100	10-10.0	
	4	10-8.0	0.08		10-10.0		20	10-9.2	0.16		10-10.0			10-10.0	
	7	10-9.5	0.04		10-10.0		30	10-9.5	0.15		10-10.0			10-10.0	
	60	10-9.9	0.06		10-10.0		45	10-9.8	0.09		10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
		10-10.0			10-10.0			10-10.0			10-10.0			10-10.0	
	80	Sub T	0.43	2	Sub T	0.06	100	Sub T	0.49	100	Sub T	0.00	100	Sub T	0.00
		Total	5.43		Total	47.06		Total	0.49		Total	0.00		Total	0.00

Summary

	Grooves 1	Grooves 2	Grooves 3	Lands 1	Lands 2	Lands 3	Upper Skirt	Under Crown	Pin Bores Front	Pin Bores Rear
Rating	26.25	7.20	0.42	5.43	47.06	0.49	0.17	1.26	0.00	0.00
WDK LOC FCT	1.5	1.5	25	1	1	25	50	20	0	0
WT Rating	39.38	10.80	10.50	5.43	47.06	12.25	8.50	25.20	0.00	0.00

TGF: 7 | Intermidate Groove Fill: 3 | WDK / WDN: 159.1 | Top Land Heavy Carbon: 0

1K/1N

Supplemental Piston Deposits (Groove Sides and Rings)

Form 5

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Deposit Type			Carbon			Varnish									
			HC	MC	LC	8 - 9	7 - 7.9	6 - 6.9	5 - 5.9	4 - 4.9	3 - 3.9	2 - 2.9	1 - 1.9	>0 - 0.9	Clean
Groove Top and Bottom	1	T	10		90										
		B				20				30	50				
	2	T			20	80									
		B								30	10	60			
	3	T										20	80		
		B										20	80		
Top Bottom and Back of Rings	1	T				20			10	10	15	15	30		
		B												100	
		BK			100										
	2	T			5	5						50	20	20	
		B									20	30	50		
		BK			40						10	50			
	3	T										30	45	25	
		B										10	15	75	
		BK										25	75		

Additional Deposit & Condition Ratings	
Piston Crown	Normal.
Liner	Normal.
Rings	Normal.

1K/1N
Oil Analysis and Results Summary
Form 6

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			
Test Method: 1N	**Test Fuel:** JP-8	**Fuel Batch:**	

Oil Analysis / Engine Hours		NEW / 0		24		204		252	
Viscosity @ 100°C		10.27		9.67		9.68		9.73	
TBN D4739		9.69		8.85		6.12		5.85	
Wear Metals:	Fe / Al	2	<1	15	<1	48	<1	55	<1
	Si / Cu	5	<1	4	3	6	6	8	6
	Cr / Pb	2	<1	1	<1	2	<1	2	<1
Fuel Dilution %		[redacted]		0.3		0.3		0.3	
Blowby (L/min)				14.0		13.9		14.3	

24 Hour Average BSOC (g/w-W-h) for Hours End				0-252 Hr. Avg. BSOC (g/k-W-h): 0.13		EOT Oil Consumption(g/kW-h): 0.10			
24	48	72	108	132	156	180	204	228	252
0.18	0.14	0.14	0.11	0.13	0.14	0.12	0.15	0.12	0.09

Inspection and Measurement Summary	**Ring Gap Increase (mm)**	**Side Clearance Loss (mm)**	**Ring Stuck (1)**	**Scuffed Area % (2)**	**% Bore Polish (With Grid)**	**Average Wear Step (mm)**
Top Ring	0.026	0.035	NO	0	[redacted]	
Intermediate Ring	0.025	0.061	NO	0		
Oil Ring	0.000	0.000	NO	0		
Piston	[redacted]			0		
Cylinder Liner				0	7.0	0.022

Piston Deposit Summary	TGF %	Int. Gr. F.%	WDK	Un Wt Dep	T.L. Heavy Carbon	T.L. Flaked Carbon %
	7	3	159.1	88.3	0	0

Unweighted Piston Deposits

Grooves			**Lands**			**Upper Skirt**	**Under Crown**	**Pin Bores**	
1	2	3	1	2	3			Front	Rear
26.25	7.20	0.42	5.43	47.06	0.49	0.17	1.26	0.00	0.00

1K/1N
Unscheduled Downtime & Maintenance Summary
Form 7

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Number of Downtime Occurrences: 0

Test	Date	Downtime	Reasons
Total Downtime			

Other Comments

Number of Comment Lines: 2

Due to the use of JP-8 fuel instead of the official PC-9
fuel, this test was determined to be non interpretable.

1K/1N
Ring Measurements
Form 8

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Ring Gaps (mm)	Top	Intermediate	OIL
Specifications	0.724 ± 0.076 mm	0.673 ± 0.076 mm	0.572 ± 0.190 mm
Pre-Test	0.711	0.635	0.483
Post-Test	0.737	0.660	0.483
Increase	0.026	0.025	0.000

Ring Side Clearance *		A	B	C	D	Average	Minimum	Specification
Top	Pre-Test	0.190	0.190	0.190	0.190	0.190	0.190	0.193±0.032 mm
	Post-Test	0.165	0.152	0.152	0.152	0.155	0.152	
	LSC	0.025	0.038	0.038	0.038	0.035	0.025	
Intermediate	Pre-Test	0.089	0.089	0.089	0.076	0.086	0.076	0.090±0.020 mm
	Post-Test	0.025	0.025	0.025	0.025	0.025	0.025	
	LSC	0.064	0.064	0.064	0.051	0.061	0.051	
Oil	Pre-Test	0.064	0.064	0.064	0.064	0.064	0.064	0.073 ±0.016 mm
	Post-Test	0.064	0.064	0.064	0.064	0.064	0.064	
	LSC	0.000	0.000	0.000	0.000	0.000	0.000	

* Notes:

1. Write "Stuck" In Place of Dimension When Applicable.

2. Write "<0.038 mm" For Clearance When Applicable.

3. Write ">" Before Calculated Decrease or Average Decrease Values That Incorporate a "<0.038 mm" in Calculation.

4 LSC: Loss of Clearance.

5. Minimum: Intermediate and Oil Ring Minimum Side Clearance is Measured 360° Around Piston.

1K/1N
Liner Measurements
Form 9

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Liner Surface Finish (micrometer)			
Distance From Top	**Transverse**	**Longitudinal**	**Average**
130 mm			
50 mm			
25 mm			
		Total Average:	

% Liner Bore Polish - Grid (Add T/AT Values From Grid)	
Thrust	3.0
Anti-Thrust	4.0
Total	7.0

Liner Bore Measurement (mm)				
Before Test - Diameter (Dial Bore Gage)				
Bore Height	**Longitudinal**		**Transverse**	
230 mm	137.160		137.193	
130 mm	137.165		137.196	
50 mm	137.165		137.196	
25 mm	137.175		137.203	
15 mm	137.165		137.190	
After Test - (Surface Profile)				
	Longitudinal		**Transverse**	
	Front	Rear	T	AT
Wear Step @ 15mm	0.023	0.020	0.023	0.020

1K/1N
Characteristics of the Data Acquisition System
Form 10

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Parameter (1)	Sensing Device (2)	Calibration Frequency (3)	Record Device (4)	Observation Frequency (5)	Record Frequency (6)	Log Frequency (7)	System Response (8)
Operation Conditions							
Engine Speed (r/min)	Magnetic Pickup	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.1
Engine Power (kW)	Load Cell	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	1.9
Fuel Flow (kJ/min)	Micro-Motion	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	70.3
Humidity (g/kg)	Dew Cell	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	6.0 min
Temperatures (°C)							
Coolant Out	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Coolant In	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.7
Oil to Bearing	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Oil Cooler In	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Inlet Air	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Exhaust	Thermocouple	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Pressure (kPa)							
Oil to Bearing	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.9
Oil to Jet	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.0
Inlet Air	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	1.0
Exhaust	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Fuel @ Filter HSG	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	2.8
Crankcase Vacuum	Strain-gage	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0
Flows (L/min)							
Blowby	Gas Meter	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	10.0
Coolant Flow	Barco Venturi	Every 5 Tests	HP 1000 Computer	Every Second	Every Minute	Every Minute	3.0

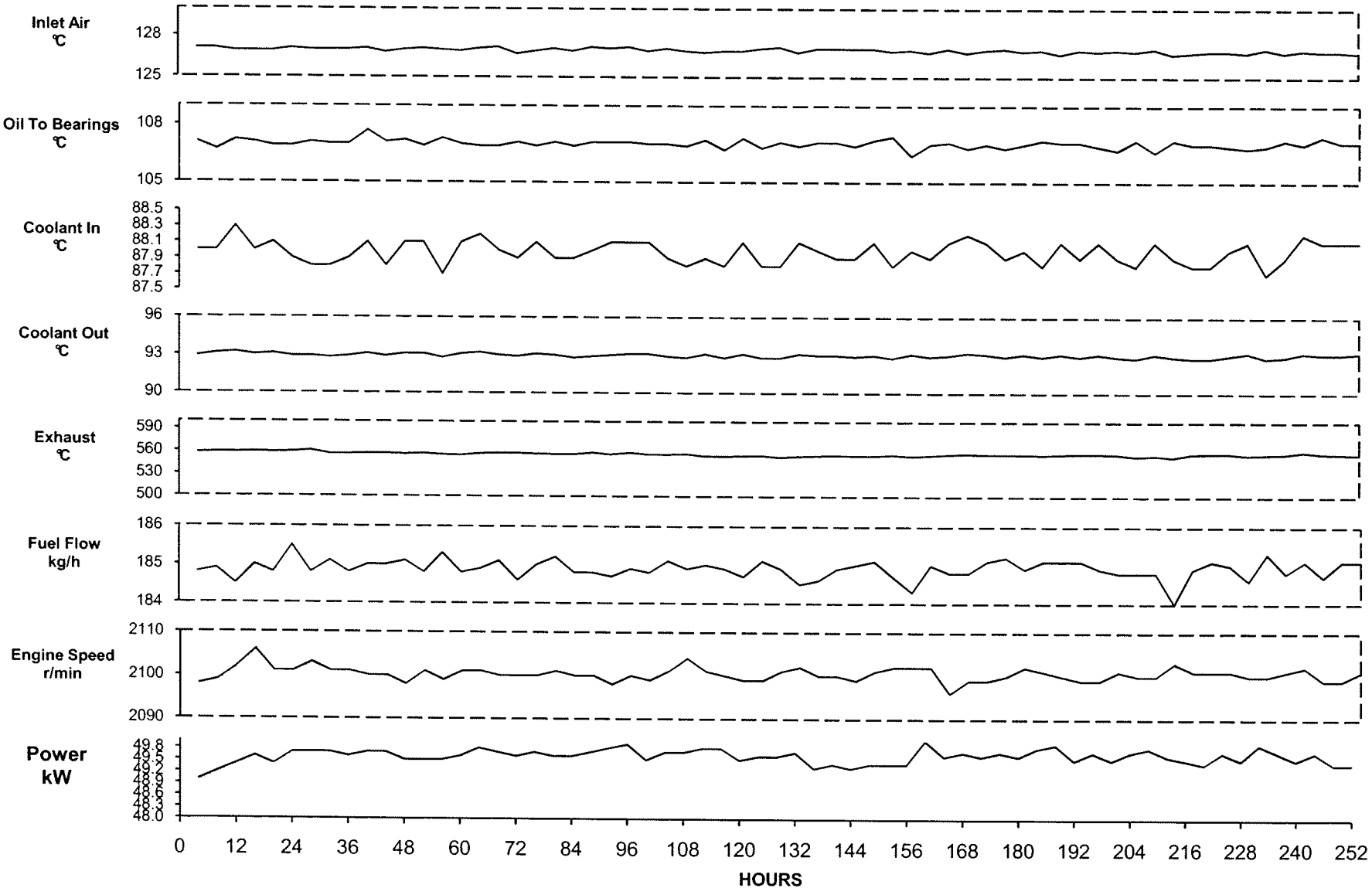
Legend:
(1) Operating Parameter
(2) The Type of Device Used to Measure Temperature, Pressure, or Flow
(3) Frequency at Which the Measurement System is Calibrated
(4) The Type of Device Where Data is Recorded
- LG - Hanglog Sheet
- DL - Automatic Data Logger
- SC - Strip Chart Recorder
- C/M - Computer, Using Manual Data Entry
- C/D - Computer, Using Direct I/O Entry

(5) Data Area Observed but Only Recorded if off Spec.
(6) Data are Recorded but are not Retained at EOT
(7) Data are Logged as Permanent Record, Note Specify if:
- SS - Snapshot Taken at Specified Frequency
- AG/X - Average of X Data Points at Specified Frequency

(8) Time for the Output to Reach 63.2% of Final Value for Step Change at Input

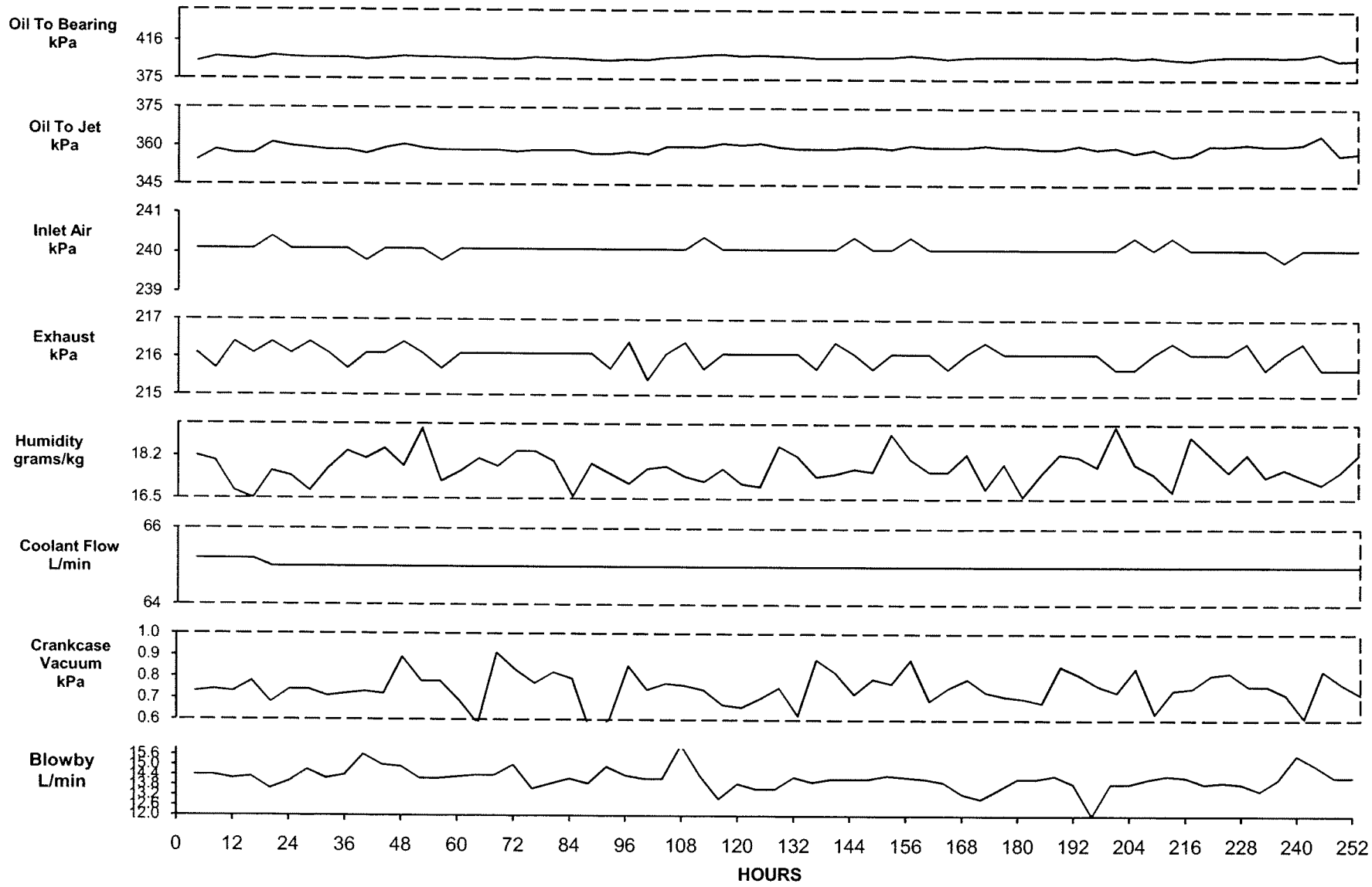
1K/1N
Form 11

Laboratory: SR	EOT Date: 20100307	EOT Time: 10:21	METHOD: 1N
TEST NUMBER			
STAND: 62	RUN NUMBER: 243		
FORMULATION/STAND CODE:			
OIL CODE:	ARMY LAB WD10 ADDITIVE LUBRICANT		



1K/1N
Form 12

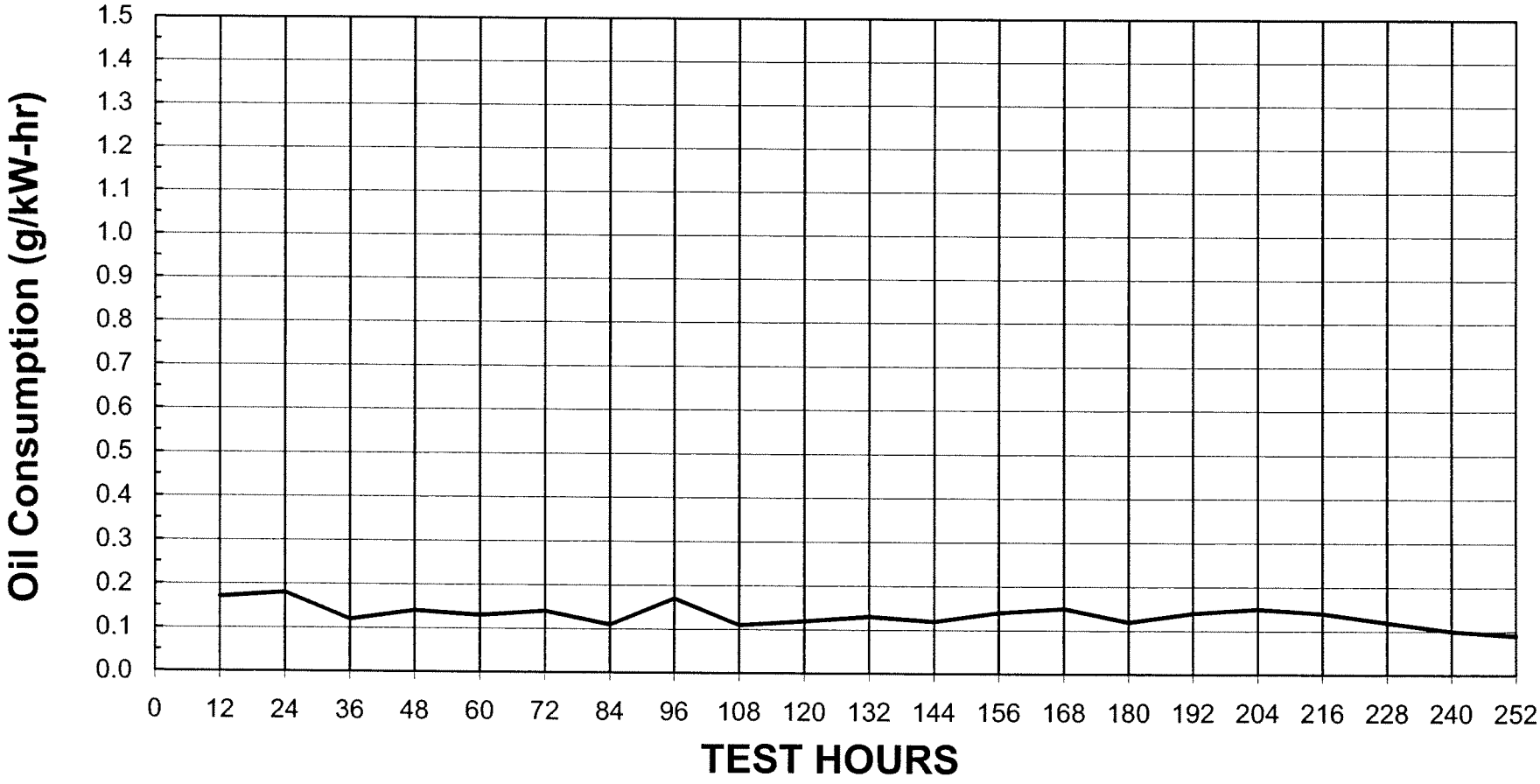
Laboratory: SR	EOT Date: 20100307	EOT Time: 10:21	METHOD: 1N
TEST NUMBER			
STAND: 62	RUN NUMBER: 243		
FORMULATION/STAND CODE:			
OIL CODE:	ARMY LAB WD10 ADDITIVE LUBRICANT		



1K/1N
Form 13
Oil Consumption Plot

Laboratory: SR	EOT Date: 20100307	EOT Time: 10:21	METHOD: 1N
	TEST NUMBER		
STAND: 62	RUN NUMBER: 243		
FORMULATION/STAND CODE:			
OIL CODE:	ARMY LAB WD10 ADDITIVE LUBRICANT		

0 - 24 Hour	0.18	
228 - 252 Hour	0.10	
Avg 0 - 252 Hour	0.13	
Increase 0 - 24 to 228 - 252 Hour	-0.08	(-45.71%)



1K/1N
Severity Adjustment History
Form 15

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Usage Dates		WDK/WDN		TGF %		Transformed TLHC %	
Start	Time	Zi	S.A.	Zi	S.A.	Zi	S.A.
20091205	07:45	-0.059	0.0	-0.345	0	-0.928	0.835
20090920	07:17	0.018	0.0	-0.294	0	-1.056	0.950
20081019	09:18	-0.017	0.0	-0.266	0	-0.980	0.882
20080528	19:52	-0.037	0.0	-0.300	0	-0.828	0.745
20070925	10:13	0.199	0.0	-0.286	0	-0.695	0.625
20070110	02:31	0.071	0.0	-0.234	0	-0.528	0.000
20060114	06:11	0.092	0.0	-0.191	0	-0.263	0.000
20051118	11:31	-0.574	0.0	-0.130	0	-0.418	0.000
20041117	01:41	-0.459	0.0	-0.175	0	-0.462	0.000
20040314	16:27	-0.620	0.0	-0.066	0	-0.762	0.686
20040125	10:40	-0.248	0.0	0.121	0	-0.561	0.000
20040121	21:21	-0.279	0.0	-0.259	0	-0.549	0.000
20030125	18:08	-0.461	0.0	-0.094	0	-0.377	0.000
20020922	19:14	-0.432	0.0	-0.037	0	-0.318	0.000
20010926	02:07	-0.273	0.0	-0.061	0	-0.246	0.000
20010922	09:52	-0.208	0.0	-0.249	0	-0.155	0.000
20010814	21:55	-0.242	0.0	-0.275	0	-0.041	0.000
20010803	21:55	-0.242	0.0	-0.275	0	-0.041	0.000
20010723	01:52	-0.503	0.0	-0.126	0	-0.357	0.000
20010214	10:06	-0.289	0.0	0.162	0	-0.294	0.000
20000925	03:50	-0.128	0.0	0.059	0	-0.215	0.000
19990929	01:16	-0.212	0.0	0.314	0	-0.413	0.000
19981004	15:37	0.002	0.0	0.258	0	-0.262	0.000
19980520	03.44	0.108	0.0	0.343	0	-0.175	0.000
19971110	10:30	0.183	0.0	0.041	0	-0.022	0.000
19971103	14:25	0.338	0.0	0.114	0	-0.179	0.000

Lab: SR	**EOT Date:** 20100307	**END Time:** 10:21	**Method:** 1N
Stand: 62	**Run Number:** 243	**Total Test Length:** 252	
Formulation / Stand Code:			
Oil Code / CMIR: ARMY LAB WD10 ADDITIVE LUBRICANT			

Appendix

Photographs

1. Piston (Thrust and Anti-Thrust)
2. Pin Bores (Front and Rear)
3. Undercrown
4. Liner (Thrust and Anti-Thrust)

Caterpillar 1N

Laboratory:	SR	**Oil Code:**	ARMY LAB WD10 ADDITIVE LUBRICANT
Completion Date:	03/07/10	**Test No.:**	62-243
Formulation / Stand Code:		**Test Hours:**	252

Piston Thrust

Piston Anti-Thrust

Caterpillar 1N

Laboratory:	SR	**Oil Code:**	ARMY LAB WD10 ADDITIVE LUBRICANT
Completion Date:	03/07/10	**Test No.:**	62-243
Formulation / Stand Code:		**Test Hours:**	252

Pinbores

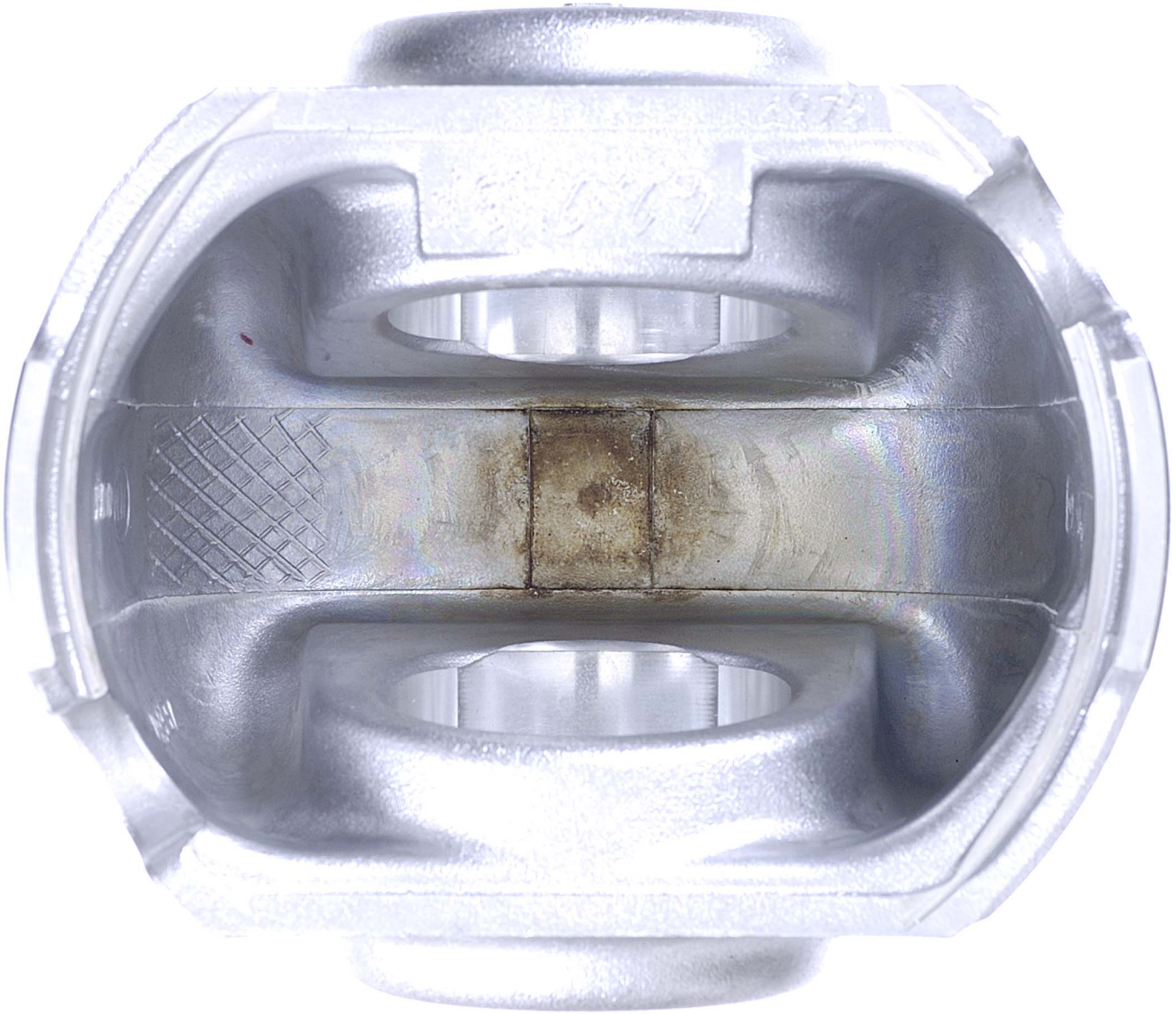
Front

Rear

Caterpillar 1N

Laboratory:	SR	**Oil Code:**	ARMY LAB WD10 ADDITIVE LUBRICANT
Completion Date:	03/07/10	**Test No.:**	62-243
Formulation / Stand Code:		**Test Hours:**	252

Undercrown

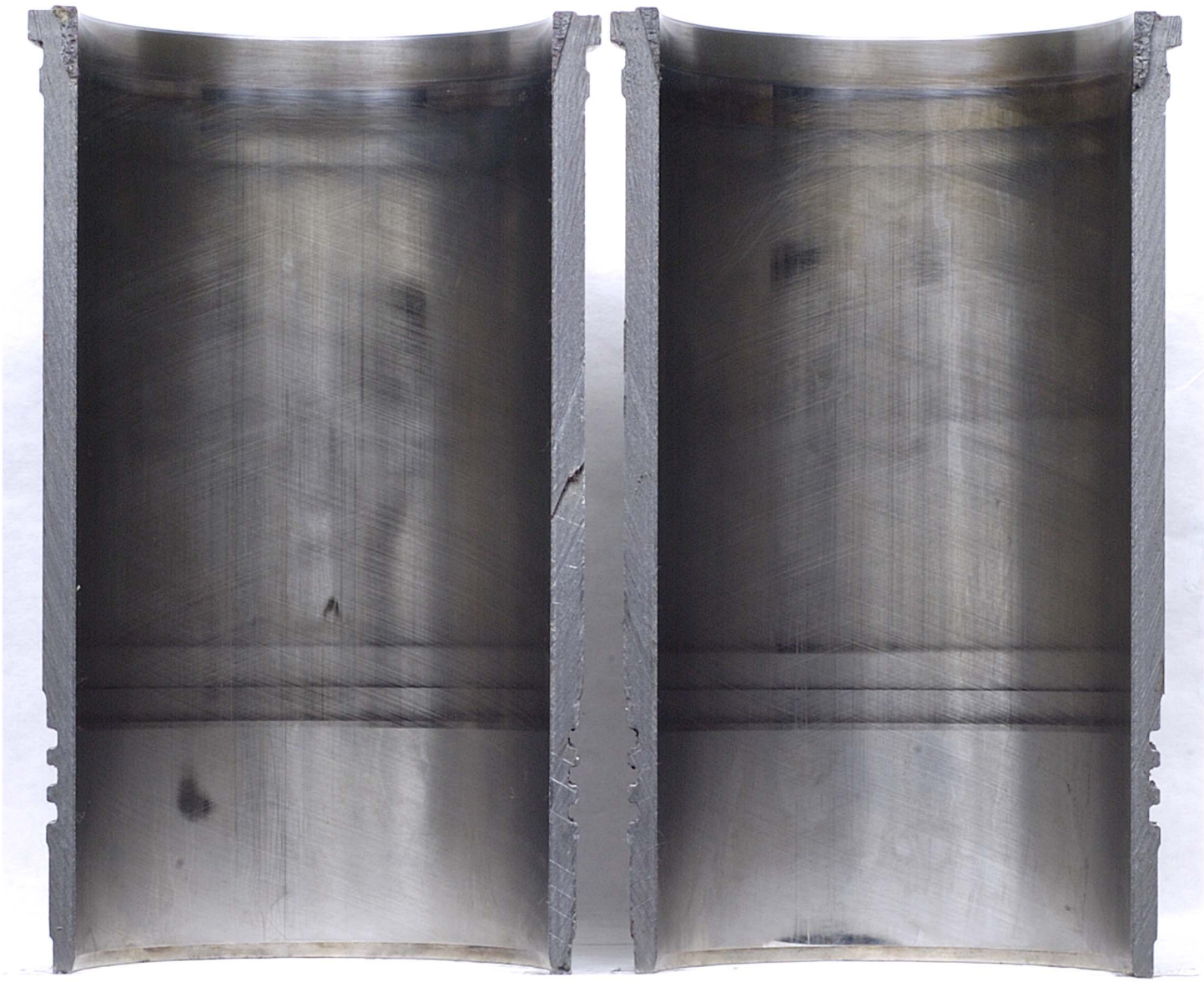


Caterpillar 1N

Laboratory:	SR	**Oil Code:**	ARMY LAB WD10 ADDITIVE LUBRICANT
Completion Date:	03/07/10	**Test No.:**	62-243
Formulation / Stand Code:		**Test Hours:**	252

Liner

Thrust **Anti-Thrust**



APPENDIX F
JP-8 Certificate of Analysis

AGE REFINING, INC.

Product Name: JP-8

Tank: 424
Batch: 2009-DO
Date: 12/11/09
MIL-DTL-83133E

7811 S. Presa
San Antonio, Texas 78223
(210) 532-5300
(210) 532-7222 Fax

Analysis	ASTM Method	Specifications		Tank Results
		Min	Max	Results
Color, Saybolt	D 156		Report	+19
Total Acid, mg KOH/g	D 3242		0.015	0.011
Aromatics, vol%	D 1319		25	14.9
Olefins, vol%	D 1319		5.0	0.7
Naphthalenes, vol%	D 1319		3.0	N/R
Sulfur, Doctor test	D 4952	Neg		Neg
Total Sulfur, mass%	D 2622		0.300	0.008
Distillation temperature, °C	D 86			
•IBP			Report	146
•10% recovered, temp			205	163
•20% recovered, temp			Report	170
•50% recovered, temp			Report	194
•90% recovered, temp			Report	243
•End Point, temp			300	266
•Residue, vol%			1.5	1.3
•Loss, vol%			1.5	0.0
Flash Point, °F	D 93	100		102
Gravity, API, at 15°C	D 1298	51.0	37.0	46.9
Freeze Point, °C	D 2386		-47	-47.50
Viscosity @ -20°C	D 445		8.0	3.41
Heat of combustion, BTU/lb	D 3338	18,400		18,654
Hydrogen content, mass%	D 3701	13.4		14.03
Smoke Point, mm	D 1322	19		26.0
Copper corrosion, 2 hr @ 100°C	D 130		1	1A
Thermal Stability test @ 275° C	D 3241			
• Pressure drop, mm Hg			25	0.0
• Tube deposit code			3	1
Existent gum, mg/100 ml	D 381		7	0.2
Particulate matter, mg/L	D 5452		1	0.42
Filtration time, minutes	D 5452		15	5
Water reaction	D 1094			
•Interface rating			1b	1
Microseparometer	D 3948	70		71
Corrosion Inhibitor, Nalco 5403 g/m³		12	22.5	17.8
Moisture, ppm	D 6304		Report	89
Fuel System Icing Inhibitor*	D 5006	0.10	0.15	0.121
Calculated Cetane Index	D 976		Report	44.9
SDA** pS/m	D2624	150	450	

Report Date: 12/11/09

Analysis performed by: __

* Diethylene Glycol Monomethyl Ether
** Stadis 450